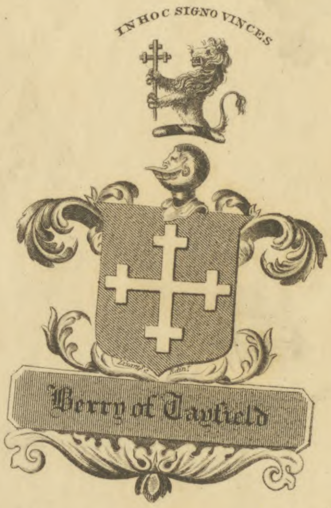
IN HOC SIGNO VINCES
Berry of Tayfield

SUPPLEMENT

TO THE THIRD EDITION OF THE

ENCYCLOPÆDIA BRITANNICA,

OR, A

DICTIONARY

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 induftry, which, whatever be thought of my other merits, I am confcious have been great, no man can be more fenfible than myfelf, that the Encyclopædia Britannica, even with the addition of this Supplement, is ftill imperfect. It would continue to be fo, were another Supplement added to this by the moft learned and laborious man on earth ; for perfection feems to be incompatible with the nature of works conftructed on fuch a plan, and embracing fuch a variety of fubjects.

No candid reader will fuppofe that, by expreffing myfelf thus, I mean to cenfure the plan of the Encyclopædia Britannica in particular ; for, to the general excellence of that plan I have elfewhere borne my teftimony, which I have yet feen no reafon to retract. Experience has indeed led me to think, that it is fufceptible of fuch improvements as would enable the principal Editor to carry the work *nearer* to perfection, even with lefs trouble to himfelf ; but the purchafers of the third edition and this Supplement need not regret the want of thofe improvements, for they are fuch as few would difcern, who have not paid the fame attention that I have done to dictionaries of arts, fciences, and literature.

Before I take leave of the reader, I muft account for the omiffion of one or two articles (chiefly biographical) which I had given him reafon to expect in thefe volumes. It was my intention at firft to introduce into the Supplement articles on every fubject which had been admitted into the Encyclopædia itfelf ; and hence in the firft fupplementary volume will be found biographical fketches of men whofe characters, though in fome refpects remarkable, have very little connection with fcience, arts, or literature. From this part of the original plan I was foon obliged to deviate. So many applications were made to me to infert accounts of perfons who, whatever may have been their private virtues, were never heard of in the republic of letters, that I was under the neceffity of excluding from the fecond volume the lives of *all* fuch as had not either been themfelves eminent in literature, or in fome liberal art or fcience, or been confpicuous as the *patrons* of fcience, arts, and literature, in others. Hence the omiffion of the life referred to from Aubigne in the firft volume, and of one or two others to which references are made in the fame way. The life of Mr James Hay Beattie of Aberdeen, whofe originality of genius, ardent love of virtue, and early and extenfive attainments in fcience and literature, raife him almoft to the eminence of Barretier, of whom we have fo pathetic an account from the pen of Johnfon, I omitted with regret ; but I thought not myfelf authorized to publifh what his father had then only diftributed among a few particular friends. For the omiffion of the life of Soame Jenyns I can make no apology : it was the confequence of forgetfulnefs.

For the *errors* of thefe two volumes, whether typographical or of a nature more important, I have perhaps no occafion to folicit greater indulgence than will be voluntarily extended to me by a generous Public. Some errors I have corrected in this fecond impreffion, and fome deficiencies I have fupplied ; but I was reftrained by thofe who are now Proprietors of the Work from making any *addition* to the firft volume, or any confiderable *alteration* in the firft part of the fecond. Hence the different conclufions which the reader will obferve in the articles Galvanism and Torpedo, refpecting the nature of the *Galvanic* power. Of thefe articles, the former was furnifhed by a friend, whofe name I am not at liberty to publifh ; but whofe reafonings appeared to me too worthy of attention to be either omitted or abridged, though they lead to a conclufion which facts more recently afcertained feem to fet afide. Thefe facts I felt it my duty to ftate to the public ; and, under the title Torpedo, I have been enabled to ftate them with the precifion and regularity of arrangement which characterife the writings of Dr Thomfon.

SUPPLEMENT

TO THE

ENCYCLOPÆDIA BRITANNICA.

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° 17, 136, 173. It should have referred him to OPTICS, n° 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° 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; (Plate II. fig. 1.) then, by the composition of these two motions, the particle of light will seem to describe the line BA or DC,

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.) (Plate II.) The abscis 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-

meter

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 abscisses, terminated all at one end by the same fixed point. In the common parabola (fig. 4.), each ordinate PQ has but one abscis AP. In the ellipse or circle (fig. 2.), the ordinate has two abscisses lying on the opposite sides of it. In general, to each ordinate a line of the second kind, or a curve of the first kind, may have two abscisses; a line of the third order, three; a line of the fourth order, four; and so on.

ABSORPTION, in ANATOMY and PHYSIOLOGY, has been sufficiently explained under these articles in the Encyclopædia; but there is another absorbing power possessed by different substances, which is worthy of attention, because 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 substances; such as wool, cotton, silk, and linen, to absorb or attract moisture from the atmosphere. On this subject the reader will find some very instructive experiments detailed (in Encycl.), where perhaps he may not have looked for them, under the title FLANEL.

ABSURDUM, a term made use of by mathematicians when they demonstrate any truth, by showing that its contrary is impossible, or involves an absurdity. Thus Euclid demonstrates the truth of the fourth proposition of the first book of his Elements, by showing that its contrary implies this obvious absurdity—"that two straight lines may inclose a space."

This mode of demonstration is called *reductio ad absurdum*, and is every whit as conclusive as the direct method; because the contrary of every falsehood must be truth, and of every truth, falsehood.

The young geometrician, however, does not, we believe, feel himself so perfectly satisfied with a demonstration of this kind, as with those which, proceeding from a few self-evident truths, conducts him directly, by necessary consequences, to the truth of the proposition to be proved. The reason is, that he has not yet learned to distinguish accurately between the words *false* and *impossible*, *different* and *contrary*. Many *different* assertions may be made relating to the same thing, and yet be all true or all false; but it is impossible to make two assertions directly *contrary* to each other, of which the one shall not be true and the other false. Thus, "snow is white," "snow is cold," are different assertions relating to the same thing, and both true; as, "snow is black," "snow is red," are both false: but let it be remembered, that of the first and second, and of the third and fourth of these assertions, neither is directly *contrary* to the other; nor is any one of them, abstractly considered, *impossible*, or such as a blind man, who had never felt nor heard of snow, might not believe upon ordinary testimony. But were all the men in Europe to tell a native of the interior parts of Africa that snow is a thing at once *white and not white, cold and not cold*, the woolly-headed savage would know as well as the most sagacious philosopher, that of these *contrary* assertions the one *must be true* and the other *must be false*. Just so it is with respect to Euclid's fourth proposition. Had he proved its truth by showing that its contrary involves this proposition, that "the diagonal of a square is commensurate with its side," the skilful geometrician would indeed have admitted the demonstration, because he knows well that the diagonal of a square is *not* commensurate with its side; but the tyro in geometry would have been no wiser than before. He knew from the beginning, that the proposition and its contrary cannot both be true; but which of them is true, and which false, such a demonstration could not have taught him, because he is ignorant of the incommensurability of the diagonal and side of a square. No man, however, is ignorant, that two straight lines cannot inclose a space; and since Euclid shows that the contrary of his proposition implies this absurdity, no man of common sense can entertain a doubt but that the proposition itself must be true.

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

ACTION is a term which has been sufficiently explained in the Encyclopædia; but since that article was written, questions have been agitated respecting *agents*, *agency*, and *action*, which, as they have employed some of the most eminent philosophers of the age, and are connected with the dearest interests of man, are certainly entitled to notice in this place.

It is the opinion of Dr Reid, and we have adopted it (see METAPHYSICS, n° 109, &c. Encycl.), that no being can be an *agent*, or perform an *action*, in the proper sense of the word, which does not possess, in some degree, the powers of will and understanding. If this opinion be just, it is obvious, that what are called the powers of nature, such as *impulse*, *attraction*, *repulsion*, *elasticity*, &c. are not, strictly speaking, *powers* or *causes*, but the effects of the agency of some active and intelligent being; and that *physical causes*, to make use 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 whose acuteness is equalled only by his virtues; and we shall consider some of his objections to it in another place (see CAUSE): but a question of a different kind falls under our present consideration; and perhaps the answer which we must give to it, may go far to remove the objections to which we allude.

Can an agent operate where, either by itself or by an instrument, it is not present? We think not; because agency, or the exertion of power, must be the agency of something. The constitution of the human mind compels us to attribute every action to some *being*; but if a being could act in *one* place from which it is absent, it might do the same in a second, in a third, and in all places; and thus we should have action without an agent: for to be absent from all places is a phrase of the same import as not to exist. But if a living and intelligent being cannot act but where it is either immediately or instrumentally present, much less surely can we attribute events of any kind to the agency of an absent and inanimated body. Yet it has been said, that "we have every reason, which the nature of the subject and of our own faculties can admit of, to believe, that there are among things inanimate such relations, that they may be mutually causes or principles of change to one another, without any exertion of *power*, or any operation of an agent, strictly so called. Such relations, for aught that we know, may take place among bodies at great distances from one another, as well as among bodies

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 inconceiveable. 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-

 detailed

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 IRMIA, 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 *Dehli:* 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 formerly called *Roh;* and hence is derived the name of the *Rohillas*. The city which was eſtabliſhed in it by the *Afghans* was called by them *Paiſhwer* or *Paiſher*, and is now the name of the whole diſtrict. The ſects of the Afghans are very numerous; of which the principal are, *Lodi*, *Lohouni*, *Sur*, *Serwani*, *Yuſufzihi*, *Bangiſh*, *Dilazaui*, *Khetti*, *Yaſin*, *Kail*, and *Beloje*. 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*."

It

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 Vanſittart, we can add, that a very particular account of the *Afghans* has been written by the late Hafiz Rahmat *Khan*, a chief of the *Rohillahs*, 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*, *Mahomet the ſon of Geber*, and *Muhamedes Aractenſis*. 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 exercitatiſſimus.*

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. Tranſ.* for 1693, N° 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. Friſicæ*, 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° 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-Raſhid, and grandſon of Almanſor. 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 Greek 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 Sindgiar (or, according to ſome, Fingar), upon the borders of the Red Sea; by which the degree was found to contain 56⅔ 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 ſound, 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 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 so 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 Alphonsus 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 *Alphonsine 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 Alphonsus 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 Alphonsus 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 Alphonsus), in his own name, and in the name of other nobles, deprived Alphonsus 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 Alphonsus 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 Alphonsus 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 Alphonsus 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. 35.

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.

ALTITUDE

Altitude, Alum.

ALTITUDE *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 reſidue 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 carbonat 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 poduce 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

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(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 oxided 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 last 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.

Alum ‖ Amicable.

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

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 $\overline{18a^{2n}-1} \times 2a^n$ 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 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 hogsheads 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, the

Amfterdam.

the vapour iffues forth with violence, and in fome parts copioufly. This mud is fo hot, that a gentleman who inadvertently ftepped into it had his foot feverely fcalded by it. The fame caufes which have prevented vegetation on this fpot, have had the fame effect on the four cones recently thrown up. Their furfaces are covered with afhes only; nor is there the leaft appearance even of mofs on the furrounding lava, for the production of which there does not appear to have elapfed a fufficient length of time fince the cones were formed: but this is not the cafe with the lava of the great primary crater; for in thofe parts of it where the edges are more perpendicular, and where confequently the mouldering decompofed earth, having no bafis to fupport it, flides down the fides of the rock, pretty long mofs was generally found growing upon it. All the fprings or refervoirs of hot water, except one only, were brackifh. One fpring derives its fource from the high ground and ridges of the crater. The water in it, inftead of boiling upwards through the ftones and mud, as in the other fprings, flows downward with a confiderable velocity, in a fmall collected ftream. Its temperature has been found not to exceed 112 degrees. The hand could be eafily kept in it for a confiderable time. It is a pretty ftrong chalybeate. The fides of the rock whence it iffues, and of the cavity into which it falls, are incrufted with ochre depofited 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 fea on the eaftern fide, where the flood tide ftrikes violently. The rocks of lava which formed the edge of the crater on that fide 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 higheft parts of the ifland, which feems to have been originally produced by the melted lava flowing down on all fides from hence. Thus there is a gradual flope from the edges of the crater to the fea; and the lava, though very irregular, and lying in mixed ruin and confufion immediately around the crater, affumes a more uniform appearance at fome diftance, layer refting regularly upon layer, with a gradual declivity the whole way down to the fea. This difpofition of the layers is particularly obfervable in the weft fide, where they happen to terminate in an abrupt precipice. The eruptions that took place at different periods appear here diftinctly marked by the different layers that are found with regular divifions between them; the glaffy lava being undermoft, the compact next, the cellular lava next above, over it the volcanic afhes and lighter fubftances, and a layer of vegetable mould covering the whole."

The ifland appears indeed in fuch a ftate of volcanic inflammation, that from the fhips decks at night were obferved, upon the heights of the ifland, feveral fires iffuing out of the crevices of the earth, more confiderable, but in other refpects refembling fomewhat the nightly flames at Pietra Mala, in the mountains between Florence and Bologna, or thofe near Bradley in Lancafhire, occafioned by fome of the coal-pits having taken fire. In the day nothing more than fmoke could be perceived.

The length of the ifland from north to fouth is upwards of four miles, its breadth from eaft to weft about two miles and a half, and its circumference eleven miles, comprehending a furface of about eight fquare miles, or 5120 acres, almoft the whole of which is covered with a fertile foil. The ifland is inacceffible except on the eaft fide, 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 paffage of large fhips. The tides run in and out at the rate of three miles an hour, and rife perpendicularly eight or nine feet on the full and change of the moon; a northerly wind making the higheft tide. The water is eight or ten fathoms deep clofe to the edge of the crater; and in the bafon formed by the crater itfelf, the variation of the compafs was found to be nineteen degrees and fifty minutes weftward of the north pole.

On the ifland, 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 Bofton. The whole five had come laft from the Ifle of France in the Indian Ocean, and had been left on the ifland of Amfterdam, about five months before the arrival of the Lion, for the purpofe of procuring a cargo of 25,000 feal-fkins for the Canton market, which, as they had already procured 8000, they hoped to complete in about ten months more. The veffel which brought them from the Ifle of France was gone to Nootka Sound, with a view of bringing a quantity of fea-otter fkins to China; and afterwards of calling for the cargo of feal-fkins at this place, to be carried to China likewife; proceeding thus alternately to Nootka and Amfterdam ifland as long as the owners fhould find their account in it.

The feals, whofe fkins are thus an article of commerce, are found here in greater numbers in the fummer than in the winter, when they generally keep in deep water, and under the weeds, which fhelter them from the inclemency of the weather. In the fummer months they come afhore, fometimes in droves of 800 or 1000 at a time, out of which about 100 are deftroyed, that number being as many as five men can fkin and peg down to dry in the courfe of a day. Little of the oil which thefe animals might furnifh is collected, for want of cafks to put it in; part of the beft is boiled, and ferves thofe people inftead of butter. The feal of Amfterdam is the *phoca urfina* of Linnæus. The female weighs ufually from 70 to 120 pounds, and is from three to five feet in length, but the male is confiderably larger. In general they are not fhy: fometimes they plunge into the water inftantly upon any one's approach, but at other times remain fteadily on the rocks, bark, and rear themfelves up in a menacing pofture; but the blow of a ftick upon the nofe feemed fufficient to difpatch them. As the fkins alone were the objects wanted, the carcafes were left on the ground to putrefy at leifure, ftrewed in fuch numbers as to render it difficult to avoid trading on them in walking along. The people thus employed were remarkable for the fqualor and filth of their perfons, clothes, and dwelling; yet none of them feemed defirous of leaving the place before the bufinefs they came upon fhould be completed. One of them, an Englifhman, who had been a confiderable time upon the ifland on a former adventure, gave but an unfavourable account of the weather during the winter months, which are always boifterous, 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 bason 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 bason, 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 bottom 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 *duodecatemoria*, 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 hactenus desiderati ad Apollonii Pergæi doctrinam* περι νευσεων, *a Marino Ghetaldo Patritio Ragusino hujusque, non ita pridem restitutam. In qua exhibetur mechanice æqualitatum tertii gradus sive solidarum, in quibus magnitudo omnino data, æquatur homogeneæ sub altero tantum coefficiente ignoto. Huic subnexa est variorum problematum practice*, Paris, 1612, in 4to.—2. Αιτιολογια: *Pro Zetetico Apolloniani problematis a se jam pridem edito in supplemento*

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. Vieta's *Angulares Sectiones;* to which he added demonstrations of his own. Our professor was cousin-german to Mr David Anderson of Finshaugh, a gentleman who also possessed a singular turn for mathematical knowledge. This mathematical genius was hereditary in the family of the Andersons; 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 Anderson 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 Anderson'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 immoveable and extended, and forms with its tail a perfectly straight and horizontal line

Plate III.

"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 surprised swimming; for its head is the only part which it exposes above the water; and if the sportsman once miss 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.

ANTES, 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

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° 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° 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, Aperture. 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, Plate II. fig. 5.

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 withinſide, 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 the

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 Azout's proportion, as is ſhown by Dr Hook, Phil. Tranſ. N° 4."

APOCATASTASIS, or, as it ſhould be written, Apokatastasis, 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; 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.

1 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.

2 Hiſtory of architecture connected with arches.

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.

3 Origin of Greek architecture.

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 Tchilminar, 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, frize, and corniche; 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.

4 Egyptian,

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.

5 Arabian, and

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

Arch.

number of little bell tents, ſtuck cloſe together round a great one. A caravanſeray 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.

Plate I.

7 Origin of the arch.

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 ſays 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 *Lanthern 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.

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

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.

10 Difficulty of conſtructing it.

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

11 Skill and myſteries of the Dionyſiacs.

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 recogniſed 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 underſtood 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.

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.

13 Better than by the Greeks and Romans.

14 Defects of the church of St Sophia at Conſtantinople.

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 in

15 Such as are never found in a Gothic church.

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in a Gothic cathedral. Some of them appear, to a careless 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 displeased 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 *a b*, *b c*), 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*, *h i*, &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 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.

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 A*cde*B. 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 A*f*B. 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. 18 And applied.

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 A*f*B 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 thickness

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nefs of the arch-ftones as great as are thought fufficient to enfure ftability; then compute the weight of the arch ftones, and the weight of the gravel or rubbifh with which the haunches are to be filled up to the road-way. If the proportion of thefe two weights be the fame with the proportion of the weights of chain, we may reft fatisfied with the curve now found; but if different, we can eafily calculate how much muft 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 fhall get a new curve, which may perhaps require a very fmall 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 practifed this method for an arch of 60 feet fpan and 21 feet height, the arch-ftones of which were only two feet nine inches long. It was to be loaded with gravel and fhivers. We made a previous computation, on the fuppofition that the arch was to be nearly elliptical. The diftance between the points 1, 2, 3, &c. were adjufted, fo as to determine the proportion of the weights of chain agreeable to the fuppofition. The curve differed confiderably from an ellipfe, making a confiderable angle with the verticles at the fpring of the arch. The real proportion of the weights of chain, when all was trimmed fo as to fuit the road-way, was confiderably different from what was expected. It was adjufted. The adjuftment made very little change in the curve. It would not have changed it two inches in any part of the real arch. When the procefs was completed, we conftructed the curve mathematically. It did not differ fenfibly from this mechanical conftruction. This was very agreeable information; for it fhewed us that the firft curve, formed by about two hours labour, on a fuppofition confiderably different from the truth, would have been fufficiently exact for the purpofe, being in no place three inches from the accurate curve, and therefore far within the joints of the intended arch-ftones. Therefore this procefs, which any intelligent mafon, though ignorant of mathematical fcience, may go through with little trouble, will give a very proper form for an arch fubject 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, becaufe it does not fpring at right angles to the horizontal line; but this is the cafe with all curves of equilibration, as we fhall fee by and by. It is not material: for, in the very neighbourhood of the piers, we may give it any form we pleafe, becaufe the mafonry is folid in that place; nay, we apprehend that a deviation from the curve of equilibration is proper. The conftruction of that curve fuppofes that the preffure on every part of the arch is vertical; but gravel, earth, and rubbifh, exert fomewhat of a hydroftatical preffure laterally in the act of fettling, and retain it afterwards. This will require fome more curvature at the haunches of an arch to balance it; but what this lateral preffure may be, cannot be deduced with confidence from any experiments that we have feen. We are inclined to think that if, inftead of dividing the horizontal line AB in the points 1, 2, 3, &c. we divide the chain itfelf into equal parts, the curve will approach nearer to the proper form.

After this familiar ftatement of the general principle, it is now time to confider the theory founded on it more in detail. This theory aims at fuch an adjuftment of the pofition of the arch-ftones to the load on every part of the arch, that all fhall remain in equilibrio, although the joints be perfectly polifhed, and without any cement. The whole may be reduced to two problems. The firft is to determine the vertical preffure or load on every point of a line of a given form, which will put that line in equilibrio. The fecond is to determine the form of a curve which fhall be in equilibrio when loaded in its different points, according to any given law.

20 Theory founded on this principle.

The whole theory is deducible from § 27. of the article Roof. The fundamental propofition in that fection ftates the proportions between the various preffures or thrufts which are exerted at the angles of an affemblage of beams or other pieces of folid heavy matter, freely moveable about thofe angles, as fo many joints, but retaining their pofition by the equilibrium of thofe preffures. It is there demonftrated, "that the thruft at any angle, if eftimated in a horizontal direction, is the fame throughout, and may be reprefented by any horizontal line BT, fig. 8. (Roofs, fig. 10 Pl. CCCCXL); and that if a vertical line QTS be drawn through T, the thruft exerted at any angle D by the piece CD, in its own direction, will then be reprefented by BR, drawn parallel to CD; and in like manner, that the thruft in the direction ED is reprefented by BS, &c.; and, laftly, that the vertical thrufts or loads, at each angle B, C, D, by which all thefe others preffures are excited, are reprefented by the portions QC, CR, RS, of the vertical intercepted by thofe lines; that is, all thefe preffures are to the uniform horizontal thruft as the lines which reprefent them are to BT. The horizontal thruft, therefore, is a very proper unit, with which we may compare all the others. Its magnitude is eafily deduced from the fame propofition; for QS is the fum of all the vertical preffures of the angles, and therefore reprefents the weight of the whole affemblage. Therefore as QS is to BT, fo is the weight of the whole to the horizontal thruft.

21 Accommodated to the conftruction of an arch vault.

To accommodate this theory to the conftruction of a curvilineal arch vault, let us firft fuppofe the vault to be polygonal, compofed of the cords of the elementary arches. Let AVE (fig. 9.) be a curvilineal arch, of which V is the vertex, and VX the vertical axis, which we fhall confider as the axis or abfciffa of the curve, while any horizontal line, fuch as HK, is an ordinate to the curve. About any point C of the curve as a centre defcribe a circle BLD, cutting the curve in B and D. Draw the equal cords CB, CD. Draw alfo the horizontal line CF, cutting the circle in F. Defcribe a circle BCDQ paffing through B, C, D. Its centre O will let in a line COQ, which bifects the angle BCD; and C d, which touches this circle in C, will bifect the angle b C d, 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 F a, cutting the cords BC, CD, in b and d, and the tangent to the circle BCDQ in c. Laftly, draw d N parallel to bc.

From what is demonftrated in § 27. of the article Roof, it appears, that if BC, CD be two pieces of an equilibrated heavy polygon, and if CF reprefent the horizontal thruft in every angle of the polygon, C d and

C b

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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.

22 And demonstrated.

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 $\epsilon\rho$, the line $R\epsilon$ drawn parallel to the tangent EG. It is evident that the angle $RE\rho$ is equal to the angle AEG. Therefore we have $ER : E\rho = \text{Rad.} : \text{Sec. Elev.}$

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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 $\frac{\text{Sec.}^3\text{ Elev.}}{\text{Rad. of Curv.}}$

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 $\frac{\text{Sec.}^2\text{ of Elev.}}{\text{Vert. Cord of Curv.}}$ 23 Corollaries.

Cor. II. If we make the arch $VC = z$, the abscissa $VH = x$, the ordinate $HC = y$, the radius osculi $CO = r$, and the $\frac{1}{2}$ vertical cord $CS = s$, the height of wall pressing on any point is proportional to $\frac{\dot{z}^3}{\dot{y}^3 r}$; or to $\frac{\dot{z}^2}{\dot{y}^2 s}$, or $\frac{\dot{x}^2 + \dot{y}^2}{\dot{y}^2 s}$. 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 $\dot{z}$, $\dot{x}$, and $\dot{y}$, 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 h. We have $\frac{1}{R} : \frac{\dot{z}^3}{\dot{y}^3 r} = H : h$, and $h = H \times \frac{\dot{z}^3}{\dot{y}^3} \times \frac{R}{r}$. The other formula gives $h = H \times \frac{\dot{z}^2}{\dot{y}^2} \times \frac{R}{s}$.

Examp. 1. Suppose the arch to be a segment of a circle, as in fig. 10. where AE is the diameter, and O the centre. In this arch the curvature is the same throughout, or $\frac{R}{r} = 1$. Therefore $h = H \times \frac{\dot{z}^3}{\dot{y}^3}$, or $= H \times \text{Cube Sec. Elev.}$ 24 Illustrated by examples.

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 h.

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. Cc 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 $\frac{1}{12}$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 $\frac{2}{3}$th of VH.

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The dotted line $v g c f$ 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 aſſymptote. 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 $v g c f$, 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 eqnilibrio 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 $\frac{1}{15}$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 $\frac{1}{25}$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 2 GV is the radius of the oſculating circle at V, and 2 DC is one-half of the vertical cord of the oſculating circle at C. Therefore $CN^2 : CK^2$ (or $\dot{y}^2 : \dot{z}^2$) $= R : s$, and $s = \frac{\dot{z}^2}{\dot{y}^2} R$. But C$c$, or $b = H \times \frac{\dot{z}^2 R}{\dot{y}^2 S}$. Therefore

$$b = H \times \frac{\dot{z}^2 \quad R}{\dot{y}^2 \frac{\dot{z}^2}{\dot{y}^2} R}, = H \times \frac{\dot{z}^2 R}{\dot{z}^2 R}, = H. \quad \text{Therefore}$$

$Cc = v$V.

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. $\frac{\dot{z}^3}{\dot{y}\ddot{x} - \dot{x}\ddot{y}}$, 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.

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25
To find the form of an arch when the figure of its back is given.

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 caſes which are moſt important and moſt difficult. Of 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 ſerieſes inſtead of accurate values.

Let $a v e$ (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 $c b$, CH. Let the thickneſs vV at the top be a, the abſciſſa $v b$ be $= \dot{u}$, and VH $= x$, and let the equal ordinates $c b$, CH be y, and the arch VC be z.

Then, by the general theorem, $cC = \frac{\dot{z}^3}{r \dot{y}^3}$, r being the radius of curvature. This, by the common rules, is $= \frac{\dot{z}^3}{\dot{y}\ddot{x} - \dot{x}\ddot{y}}$. This gives us $c\,C = \frac{\dot{y}\ddot{x} - \dot{x}\ddot{y}}{\dot{y}^3}$, or $= \frac{\dot{y}\ddot{x} - \dot{x}\ddot{y}}{\dot{y}^3} \times C$; where C 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 $= a + x - u$. Therefore $a + x - u = \frac{\dot{y}\ddot{x} - \dot{x}\ddot{y}}{\dot{y}^3} \times C, = \frac{C}{\dot{y}} \times$ fluxion of $\frac{\dot{x}}{\dot{y}}$.

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 $c v$ for its extrados. Plate II

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

Aſſume $\dot{y} = \frac{\dot{x}}{v}$; then $\frac{\dot{x}}{\dot{y}} = v$, and $\frac{C}{\dot{y}} \times$ fluxion of $\frac{\dot{x}}{\dot{y}}$, $= \frac{C v \dot{v}}{\dot{x}}$, that is $a + x = \frac{C v \dot{v}}{\dot{x}}$. Therefore $a\dot{x} + x\dot{x} = C v \dot{v}$; and by taking the fluents, we have $2ax + x^2 = C v^2$; and $v = \sqrt{\frac{2ax + x^2}{C}}$. Conſequently, $\dot{y} = \frac{\sqrt{C}\,\dot{x}}{\sqrt{2ax \times x^2}}$ (being $= \frac{\dot{x}}{v}$). Taking the fluent of this, we have $y = \sqrt{C} \times L\,(2ax + 2x^2$

+ 2

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$+ 2\sqrt{2ax + x^2})$. 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 h of the arch are given, we have $s = \sqrt{C} \times L\left(\frac{a + h + \sqrt{2ah + h^2}}{a}\right)$, and consequently $\sqrt{C} = \frac{s}{L\left(\frac{a + h + \sqrt{2ah + h^2}}{a}\right)}$. Therefore the general value of

$$y = s \times \frac{L\left(\frac{a + x + \sqrt{2ax + x^2}}{a}\right)}{L\left(\frac{a + h + \sqrt{2ah + h^2}}{a}\right)}; = \frac{s}{L\,\frac{a+h+\sqrt{2ah+h^2}}{a}} \times L\,\frac{a + x + \sqrt{2ax + x^2}}{a}.$$

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	6,055	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.

26 Defects of the Catenarian curve.

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 $v\,h$ in the constant ratio of the horizontal thrust to its excess above the pressure on the vertex.

27 Inutility of the common theory of equilibration.

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. 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 prosecuted 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 irreconcileable 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

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Its defects.

do not think it erroneous, but defective, leaving out circumstances which we apprehend to be of great importance; 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 connected 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 expressly, 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 connection 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 inconsiderable 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 occasioned 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 purpose. When this is the case, the pressures sustained by the different parts of the arch are often very inconsistent with the theory—a part of the arch is overloaded, and tends to fall in, but is prevented by the cement. This part of the arch therefore acts on the remoter 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? because he supposes that all his polished joints are perpendicular 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 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 without 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 directed 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 statical 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. 14. disposed in two straight lines, no weight laid on the crown can destroy it in any other way but by crushing it to powder.

29
When it is to be called into the aid of the builder.

But when straight lines cannot be drawn from the overloaded part to the firm abutments through the solid 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 cement 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 another force which produces the same effect, and which increases nearly in the proportion that those thrusts increase, because it arises from them. This is the friction of the stones on each other. In dry freestone this friction considerably exceeds one half of the mutual pressure. 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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adequate to all the effects we have been speaking of.

30 Process of the breaking 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° 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 curvilineal 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 downfal, 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, BC, 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 downfal. 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.

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 downfal. 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 mechanicians 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

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 overſetting. 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, dove-tailed with ſound 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 interſections of vaultings, and multiplied the arches exceedingly. Conſtant practice gave opportunities of giving every poſſible variety of theſe interſections, 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

nuity and invention. Becoming thus the dupes of their own ingenuity, they were fond of difplaying it even when not neceffary. At laft arches became their principal ornament, and a wall or ceiling was not thought dreffed out as it fhould be till filled full of mock arches, croffing and butting on each other in every direction. In this procefs in their ceilings they found that the projecting mouldings, which we now call the Gothic tracery, formed the chief fupports of the roofs. The plane furfaces included between thofe ribs were commonly vaulted with very fmall ftones, feldom exceeding fix or eight inches in thicknefs. This tracery therefore was not a random ornament. Every rib had a pofition and direction that was not only proper, but even neceffary. Habituated to this fcientific arrangement of the mouldings, they did not deviate from it when they ornamented a fmooth furface with mock arches; and in none of the highly ornamented *ancient* buildings will we find any falfe pofitions. This is by no means the cafe in many of the modern imitations of Gothic architecture, even by our beft architects. Ignorant of the directing principle, or not attending to it, in their ftucco work, they pleafe the unfkilled eye with pretty radiated figures; but in thefe we frequently fee fuch abutments of mouldings as would infallibly break the arches, if thefe mouldings were really performing their ancient office, and fupporting a vaulting of confiderable extent. Nay, this began even before the Gothic ftyle was finally abandoned. Several inftances are to be found in the highly enriched vaultings of New College, and Chrift Church in Oxford, in St George's Chapel at Windfor, and Henry the VII's Chapel in Weftminfter.

33 Degeneracy of that ftyle.

We call the middle ages rude and barbarous; but there was furely much knowledge in thofe who could execute fuch magnificent and difficult works. The working drafts which were neceffary for fuch varieties of oblique interfections muft have required confiderable fkill, and would at prefent occupy many very expenfive volumes of *mafons jewels* and *carpenters manuals*, and the like. All this knowledge was kept a profound fecret by the corporation, and on its breaking up we had all to learn again.

There is no appearance, however, that thofe architects had ftudied the theory of equilibrated arches. They had adopted an arch which was very ftrong, and permitted confiderable irregularities of preffure—we mean the pointed arch. The very deep mouldings with which it was ornamented, made the arch ftones very long in proportion to the fpan of the arch. But they had ftudied the mutual thruft of arches on each other with great care; and they contrived to make every invention for this purpofe become an ornament, fo that the eye *required* it as a neceffary part of the building. Thus we frequently fee fmall buildings having buttreffes at the fides. Thefe are neceffary in a large vaulted building, for withftanding the outward thruft of the vaulting; but they are ufelefs when we have a flat ceiling within. Pinnacles on the heads of the buttreffes are now confidered as ornaments; but originally they were put there to increafe the weight of the buttrefs: even the great tower, in the centre of a cathedral, which now conftitutes its great ornament, is a load almoft indifpenfably neceffary, for enabling the four principal columns to withftand the combined thruft of the aifles, of the nave, and tranfepts. In fhort, the more

34 Great fkill of the ancient Gothic architects.

closely we examine the ornaments of this architecture, the more fhall we perceive that they are effential parts, or derived from them by imitation: and the more we confider the whole ftyle of it, the more clearly do we fee that it is all deduced from the relifh for arcades, indulged in the extreme, and pufhed to the limit of poffibility of execution.

35 Dome or cupola

THERE is another fpecies of arch which muft not be overlooked, namely, the DOME or CUPOLA, with all its varieties, which include even the pyramidal fteeple or fpire.

It is evident that the erection of a dome is alfo a fcientific art, proceeding on the principles of equilibration, and that thefe principles admit and require the fame or fimilar modifications, in confequence of the cohefion and friction of the materials. At firft fight, too, a dome appears a more difficult piece of work than a plain arch; but when we obferve potters kilns and glafshoufe domes and cones of vaft extent, erected by ordinary bricklayers, and with materials vaftly inferior in fize to what can be employed in common arches of equal extent, we muft conclude that the circumftance of curvature in the horizontal direction, or the abutment of a circular bafe, gives fome affiftance to the artift. Of this we have complete demonftration in the cafe of the cone. We know that a vaulting in the form of a pent roof could not be executed to any confiderable extent, and would be extremely hazardous, even in the fmalleft dimenfions; while a cone of the greateft magnitude can be raifed with very fmall ftones, provided only that we prevent the bottom from flying out, by a hoop, or any fimilar contrivance. And when we think a little of the matter, we fee plainly, that if the horizontal fection be perfectly round, and the joints be all directed to the axis, they all equally endeavour to flide inwards, while no reafon can be offered why any individual ftone fhould prevail. They are all wedges, and operate only as wedges. When we confider any fingle courfe, therefore, we fee that it cannot fall in, even though it may be part of a curve which could not ftand as a common arch; nay, we fee that a dome may be conftructed having the convexity of the curve, by the revolution of which it is formed, turned towards the axis, fo that the outline is concave. We fhall afterwards find that this is a ftronger dome by far than if the convexity were outwards, as in a common arch. We fee alfo that a cone may be loaded on the top with the greateft weight, without the fmalleft danger of forcing it down, fo long as the bottom courfe is firmly kept from burfting outwards. The ftone lanthern on the top of St Paul's cathedral in London weighs feveral hundred tons, and is carried by a brick cone of eighteen inches thick, with perfect fafety, as long as the bottom courfe is prevented from burfting outwards. The reafon is evident: The preffure on the top is propagated along the cone in the direction of the flant fide; and, fo far from having any tendency to break it in any part, it tends rather to prevent its being broken by any irregular preffure from foreign caufes.

36 Of eafier conftruction than a plain arch.

For the fame reafons the octagonal pyramids, which form the fpires of Gothic architecture, are abundantly firm, although very thin. The fides of the fpire of Salifbury cathedral are not eight inches thick after the octagon is fully formed. It is proper, however, to direct

37 Proper conftruction of octagonal pyramids.

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 construction.

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.

Plate II.

Therefore, let B *b* A (fig. 17.) be the curve which produces the dome by revolving round the vertical axis AD.

39 Stability of a dome depends on principles

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 HA *b* of the dome, it is plain that it presses on the course, of which HL is an arch-stone, in a direction *b* C perpendicular to the joint HI, or in the direction of the next superior element β *b* 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 β *b*, produced in C. We may take *b c* 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 *b* F. If we form the parallelogram *b* FGC, the diagonal *b* G 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 *b* G does not coincide with the curve A *b* B, 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 *b* G falls within the curvilineal element *b* B. 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 *b* G 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 *b* C always falls below *b* B, and the point C below B. When the curve is concave downwards, as in the upper part of the figure, '*b* C' passes above, or without *b* B. The curvature may be so abrupt, that even *b'* G' shall pass without '*b* B, 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 *b* G 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.

40 Different from that of a common arch

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

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 lanthern, 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.

41 Excellency of the dome of St Paul's.

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 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.

42 Theory of the curves proper for domes.

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 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 HAh 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 $= \sqrt{\dot{x}^2 + \dot{y}^2}$. Let d be the depth or thickneſs HI of the arch-ſtones. Then $d\sqrt{\dot{x}^2 + \dot{y}^2}$ will repreſent the trapezium HL: and ſince the circumference of each courſe increaſes in the proportion of the radius y, $dy\sqrt{\dot{x}^2 + \dot{y}^2}$ 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 $\int dy\sqrt{\dot{x}^2 + \dot{y}^2}$ will repreſent the whole maſs, and alſo the weight of the vaulting down to the joint HI. Therefore we have this proportion $\int dy\sqrt{\dot{x}^2 + \dot{y}^2} : dy\sqrt{\dot{x}^2 + \dot{y}^2} = be : b\text{F}, = be : \text{CG}, = \delta d : \text{CG}, = \dot{x} : \text{CG}$. Therefore CG $= \frac{dy\dot{x}\sqrt{\dot{x}^2 + \dot{y}^2}}{\int dy\sqrt{\dot{x}^2 + \dot{y}^2}}$.

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 $\ddot{x}$, the point G coinciding with B. This condition will be expreſſed by the equation $\frac{dy\dot{x}\sqrt{\dot{x}^2 + \dot{y}^2}}{\int dy\sqrt{\dot{x}^2 + \dot{y}^2}} = \ddot{x}$, or, more conveniently, by $\frac{dy\sqrt{\dot{x}^2 + \dot{y}^2}}{\int dy\sqrt{\dot{x}^2 + \dot{y}^2}} = \frac{\ddot{x}}{\dot{x}}$.

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 $\frac{dy\sqrt{\dot{x}^2 + \dot{y}^2}}{\int dy\sqrt{\dot{x}^2 + \dot{y}^2}} > \frac{\ddot{x}}{\dot{x}}$, or by $\frac{dy\sqrt{\dot{x}^2 + \dot{y}^2}}{\int dy\sqrt{\dot{x}^2 + \dot{y}^2}} = \frac{\ddot{x}}{\dot{x}} + \frac{\dot{t}}{t}$, 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 $\frac{\dot{t}}{t}$ is $= o$.

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

ſince

since stability requires that we have $\frac{dy\dot{x}\sqrt{\dot{x}^2+\dot{y}^2}}{\ddot{x}}$ greater than $\int dy\sqrt{\dot{x}^2+\dot{y}^2}$, we learn that the upper part of the dome must not be made very heavy. This, by diminishing the proportion of b F to b C, diminishes the angle $c\,b$ G, 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 suppressed.

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

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 $\frac{dy\sqrt{\dot{x}^2+\dot{y}^2}}{a} = \frac{\dot{t}\dot{x} + t\ddot{x}}{\dot{y}}$, and $d = \frac{a\dot{t}\dot{x} + at\ddot{x}}{y\dot{y}\sqrt{\dot{x}^2+\dot{y}^2}}$, 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 $\frac{dy\dot{x}\sqrt{\dot{x}^2+\dot{y}^2}}{\int dy\sqrt{\dot{x}^2+\dot{y}^2}}$ will then be greater than $\ddot{x}$. This will give $d = \frac{pa\dot{x}^{p-1}\ddot{x}}{y\dot{y}^p\sqrt{\dot{x}^2+\dot{y}^2}}$. Each of these forms has its advantages when applied to particular cases. Each of them also gives $d = \frac{a\ddot{x}}{\dot{y}\dot{y}\sqrt{\dot{x}^2+\dot{y}^2}}$ 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 $\int dy\sqrt{\dot{x}^2+\dot{y}^2}$. 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 $= \sqrt{\dot{x}^2+\dot{y}^2}$.

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 $\frac{dy\dot{x}\sqrt{\dot{x}^2-\dot{y}^2}}{\ddot{x}} = \int dy\sqrt{\dot{x}^2+\dot{y}^2}$. Let a be the radius of the hemisphere. We have $\dot{x} = \frac{ay\dot{y}}{\sqrt{a^2-y^2}}$, and $\ddot{x} = \frac{a^2\dot{y}^2}{\overline{a^2-y^2}|^{\frac{3}{2}}}$. Substituting these values in the formula, we obtain the equation $y^2\sqrt{a^2-y^2} = \int\frac{a^2y\dot{y}}{\sqrt{a^2-y^2}}$. 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° 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.

43 Dome of St Peter's at Rome.

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 lanthern

lanthern 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° 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 B *a b* will be wholly within the elliptical arch BA *b*. 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° 2).

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 lanthern 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 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.

46 Effects of cement and friction in dome vaulting.

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.

47 The iron bridge at Sunderland deſcribed.

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.

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

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 voussoirs 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.

Plate IV.

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.

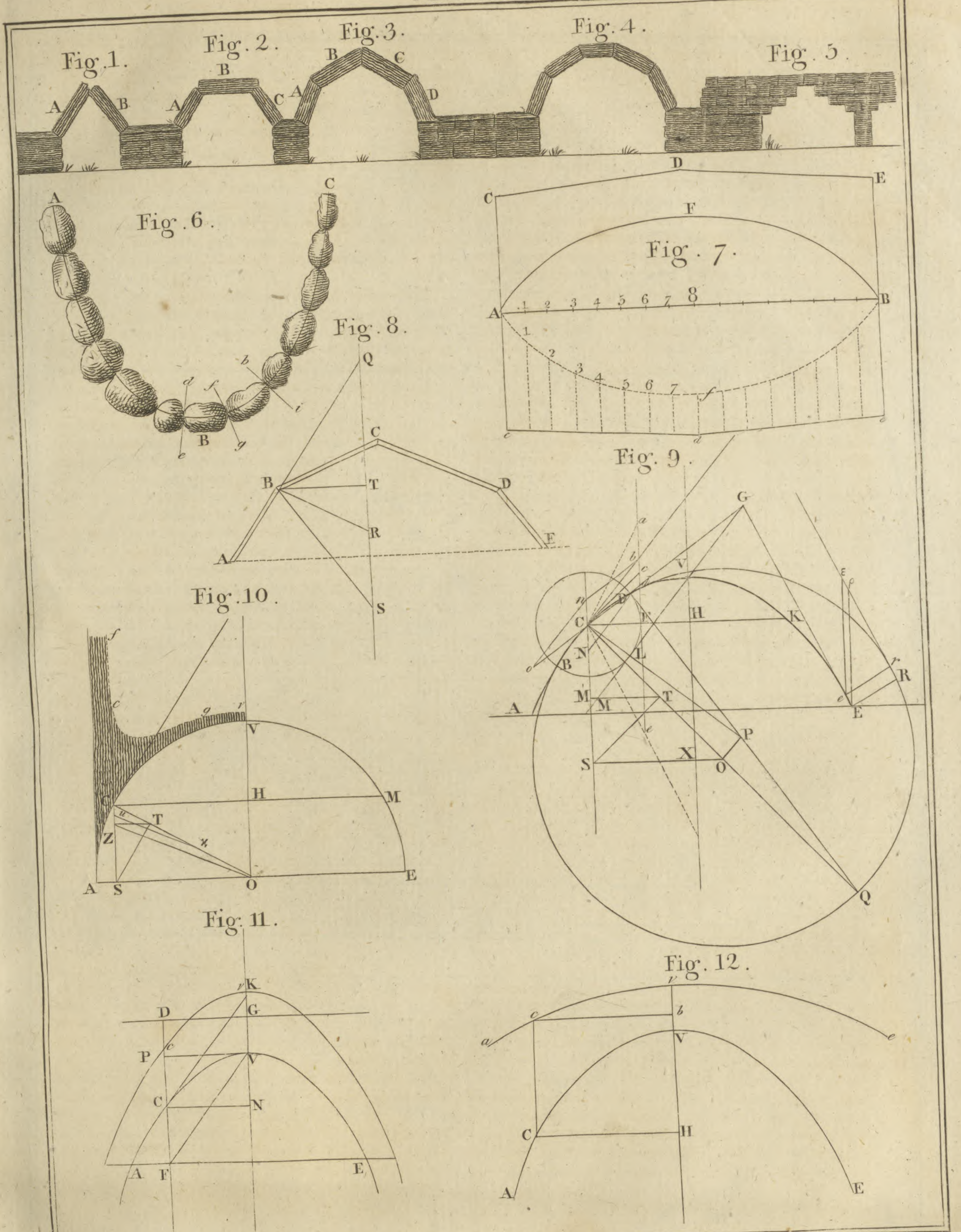
48 Its construction simple and judicious.

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 road-way. 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 road-way. The road-way 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,

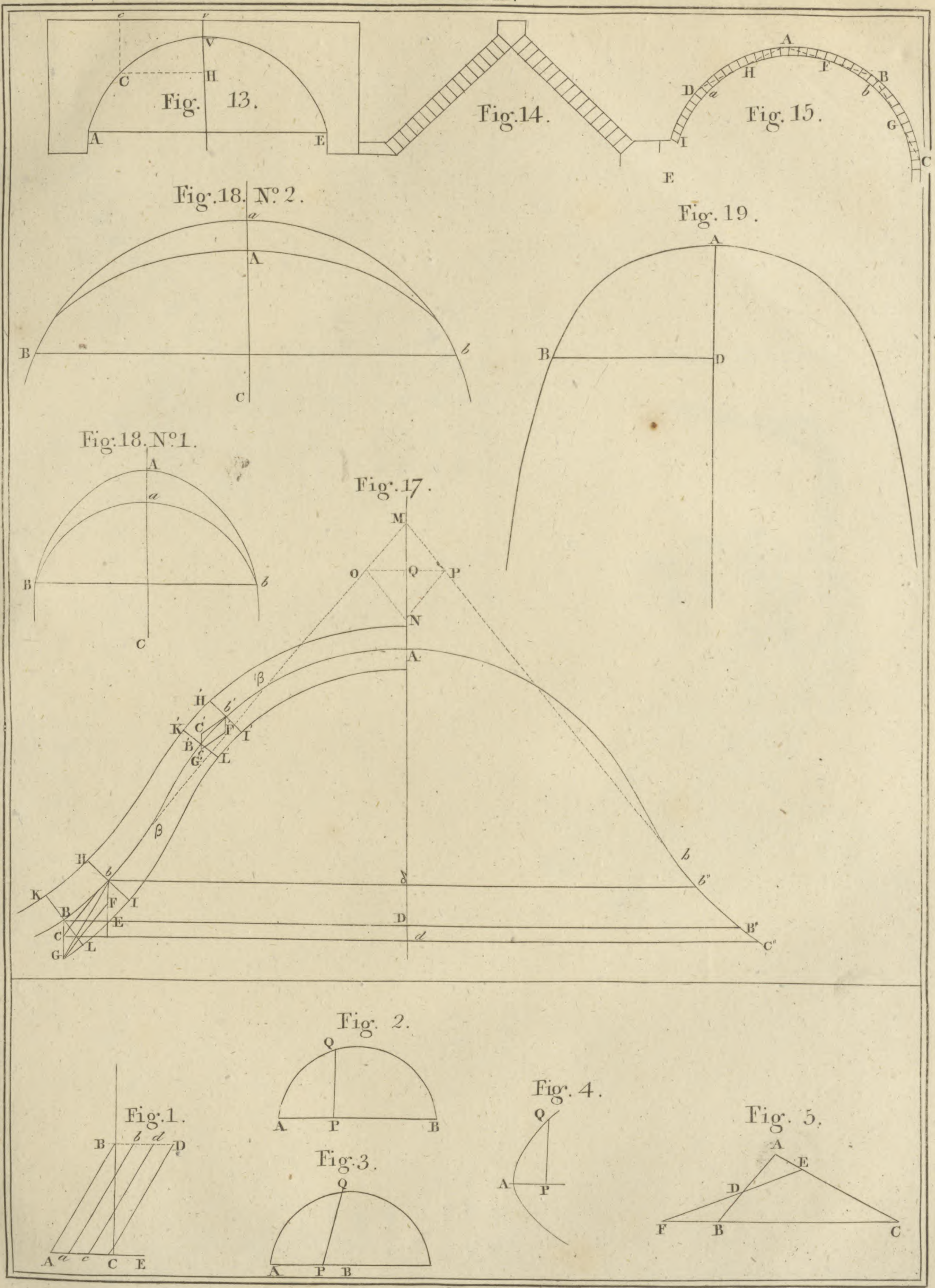
49 Though in one particular capable, perhaps, of improvement.

PLATE I.

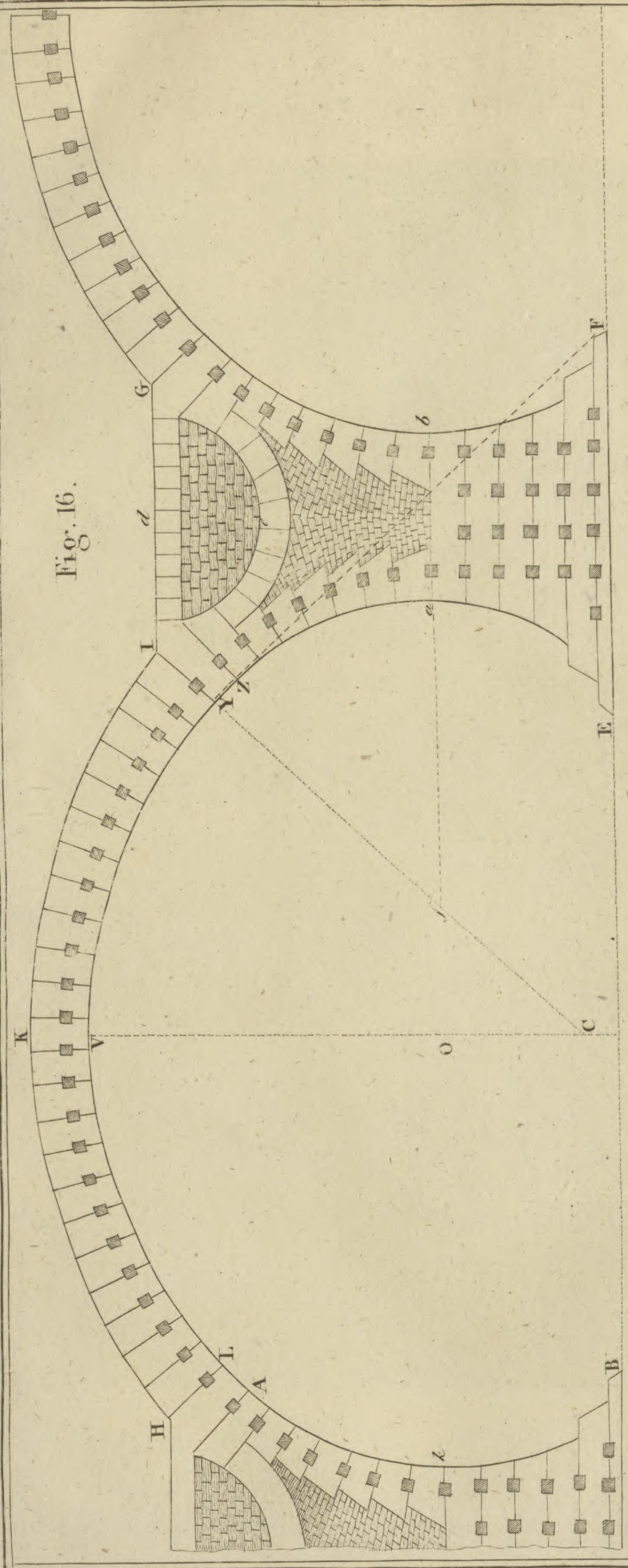


D.Lizars sculp.

PLATE II.

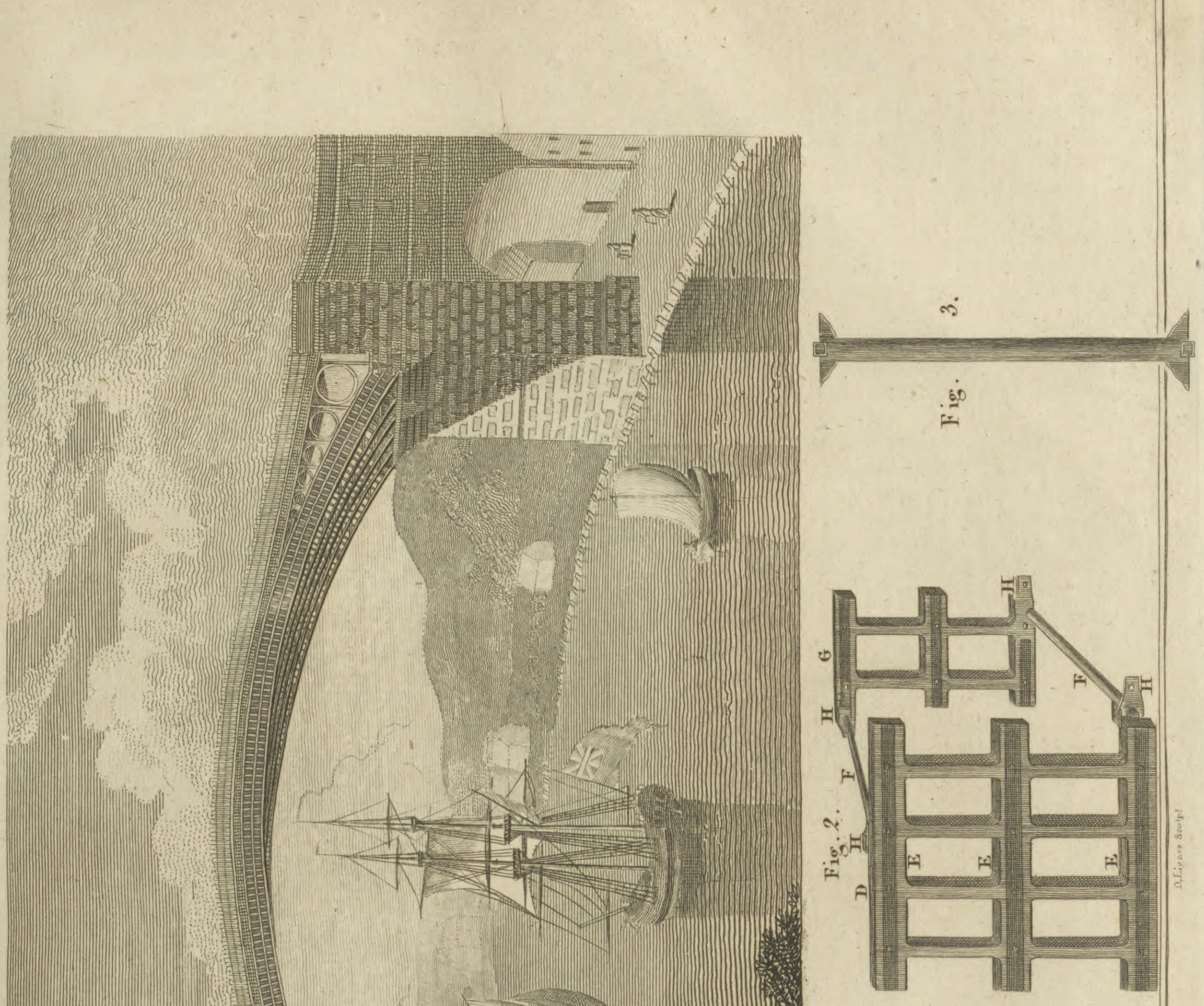


D. Lizars sculp.



MALE ANHINGA

IRON BRIDGE



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 marle, 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 pilgrams, 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."

Architecture.

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.)

Plate V.

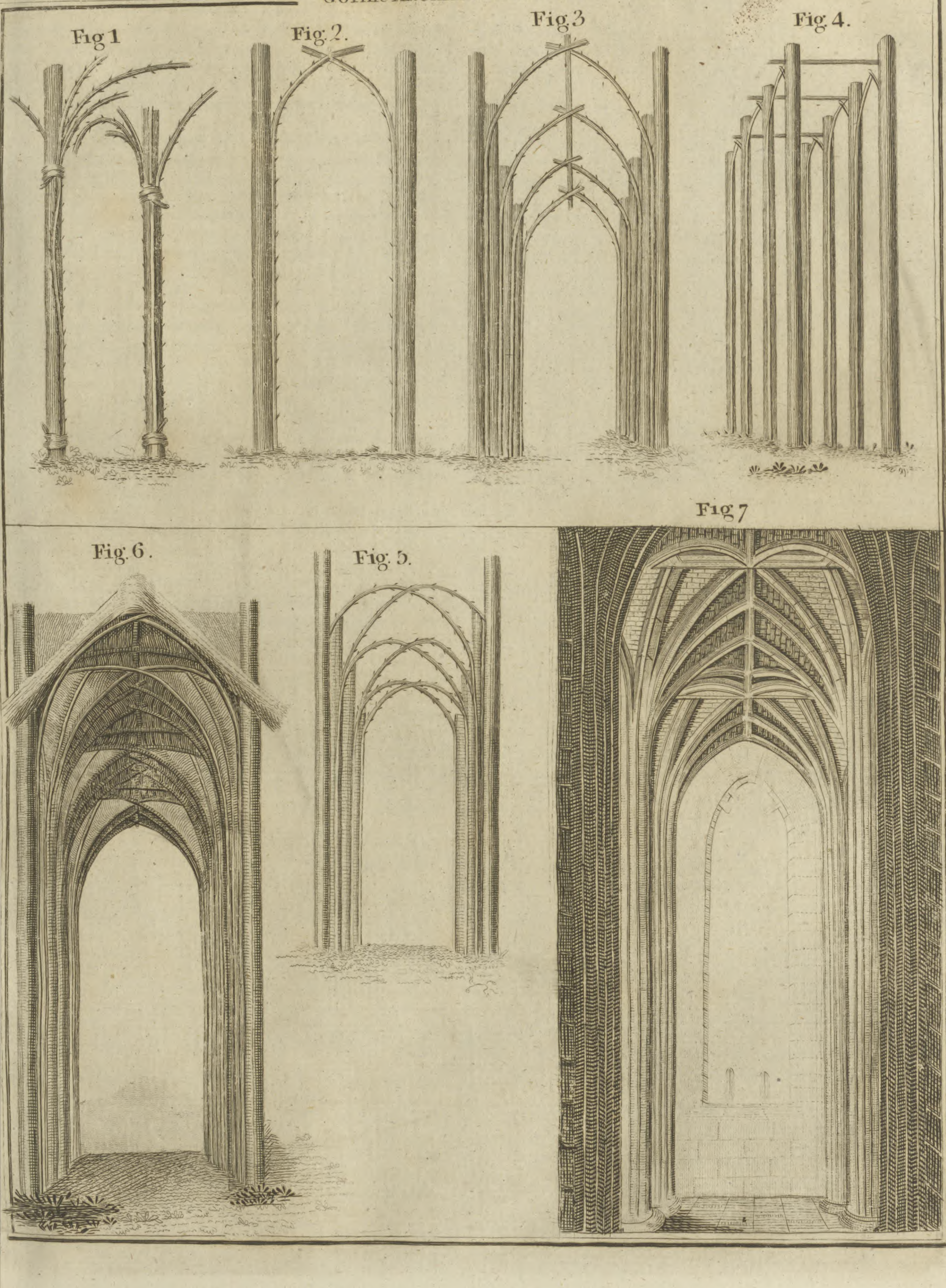
Things being thus disposed, the skeleton of a thatched roof may be formed by means of the loose ends of the rods. A rod from one of the posts being so bent as to meet a similar one from the post immediately opposite to it, in the middle of the space between them, let the two rods be made to cross each 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 of

GOTHIC ARCHITECTURE PLATE V.



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 *Tabulæ 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 arithmetic*, 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.

Tetractic 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 excellenc 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 *itchthyology*. 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, 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."

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, Kætseuter, and others. Here also are added tables containing the system of fishes by Ray, Dale, Schaeffir, 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 synonymes 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, Hasselquist, Broussonet, Leske, Buish, Linnæus, and other great examiners of nature.

ASTRONOMY

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

1 Object of this article. 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.

2 Metaphorical use of the term *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

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.

3 Our notion of a moving power.

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

4 Meaſure of moving forces.

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.

5 Accelerated motion the mark of 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.

6 And gives a meaſure of the acquired velocity.

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 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.

Plate VI.

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 curvilineal, 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, *a c* of two circles. They are deflected from the tangents AB, *a b*. Let us ſuppoſe that the direction of the deflecting forces is known to be that of the chords AE, *a e* of theſe circles. Let theſe be called the DEFLECTIVE CHORDS. Draw CB, *c b* parallel to AE, *a e*, and CD, *c d* parallel to AB, *a b*. Join AC, *a c*, CE, and *c e*. 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 *a d* are reſpectively equal to BC and *b c*. 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 *b c* being reſpectively equal to AD and *a d*, 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, *a c*. Therefore, when theſe times are diminiſhed without end, the *ultimate* ratio of AD and *a d* 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 *a c* 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 cords of thoſe circles inverſely. This ratio may be expreſſed ſymbolically thus, $F : f = \frac{V^2}{C} : \frac{v^2}{c}$; 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 *b c*, or the ſpace through which the body is actually made to deviate from rectilineal motion in the time of deſcribing the arch *a c*. It is a third proportional to *a e* the deflective chord, and *a c* 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 *b c*, 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 *a c*. 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 curvilineal motions. These two affections or properties of curvilineal 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 followers.

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 discover 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 rectilineal 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 proceeded.

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 refpective primary planets, this inference was extended to them.

15 Centripetal forces. From the circumftance 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 propofition may be deduced a corollary which eftablifhes 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 inverfely proportional to the perpendiculars drawn from the fun on the tangents to the orbit in thofe points refpectively. For, let AB, $a\,b$ (fig. 3.) be two arches (extremely fmall), defcribed in equal times, thefe arches muft be ultimately proportional to the velocities with which they are defcribed. Let SP, S p be perpendicular to the tangents AP, $a\,p$. The triangles ASB, a S b are equal, becaufe equal areas are defcribed by the *radii vectores* SA, S a, in equal times: but in equal triangles, the bafes AB, $a\,b$, are reciprocally as their heights SP, Sp, or AB : $a\,b$ = Sp : SP.

This corollary gives us another expreffion of the ratio of the centripetal forces in different points A and a of a curve. We faw by a former propofition, that the force at A (fig. 2.) is to the force at a as $AC^2 \times a\,e$ to $a\,c^2 \times AE$, which we may exprefs thus: $F : f = V^2 \times c : v^2 \times C$. If we exprefs the perpendiculars SP, S p (in fig. 3.) by the fymbols 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 inverfe duplicate ratio of the perpendiculars drawn to the tangents in thofe points from the centre of forces, and the inverfe 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 fun, or the relation which fubfifts between the intenfity of its action and the diftance of the planet from the fun: 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 fun to that tangent.

Kepler's fecond law or obfervation of the planetary motions was, that *each primary planet defcribed an ellipfe, having the fun in one focus.* It is eafy to fhow, even without any knowledge of the geometrical properties of the ellipfe, what is the proportion of the intenfities of the deflecting force at the aphelion and perihelion (fee fig. 4.) At thofe two points of the orbit, the motion of the planet is at right angles to the line joining it with the fun. Therefore, fince the areas defcribed in equal times are equal, the arches defcribed in equal times muft be inverfely at the diftances from the fun; or the velocities muft be inverfely as the diftances from the fun. But the curvature in the aphelion and perihelion is the fame; and therefore the diameters of the equicurve circles in thofe points are equal. But thofe diameters are, in this particular cafe, what we called the deflective chords. Therefore, calling the aphelion and perihelion diftances 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 inverfely as the fquares of the diftances from the fun. A perfon almoft ignorant of mathematics may fee the truth of this by looking into a table of natural verfed fines. He will obferve, that the verfed fine of one degree is quadruple the verfed fine of half a degree, and fixteen times the verfed fine of a quarter of a degree; in fhort, that the verfed fines of fmall arches are in the proportion of the fquares of the arches. Now fince the arches defcribed in equal times are inverfely as the diftances, their verfed fines are inverfely as the fquares of the diftances. But thefe verfed fines are the fpaces 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 intenfity that is proportional to the fquares of the diftances inverfely. As thefe are the extreme fituations of a planet, and as the proportion of the aphelion and perihelion diftances are confiderably different in the different planets, and yet this law of action is obferved in them all, it is reafonable to imagine that it holds true, not in thofe fituations only, but in every intermediate fituation. But a conjecture, however probable, is not fufficient, when we aim at accurate fcience, and it is neceffary to examine whether this law of action is really obferved in every point of the elliptical orbit.

For this purpofe it is neceffary to mention fome geometrical properties of the ellipfe. Therefore let ADBE (fig. 4.) be the elliptical orbit of a planet or comet, having the fun in the focus S. Let AB be the tranfverfe axis, and DE the conjugate axis, and C the centre. Let P be any point of the ellipfe. Draw PS through the focus. Draw the tangent PN, and SN from the focus, perpendicular to PN. Draw PQ perpendicular to PN, meeting the tranfverfe axis in Q. Draw QO parallel to PN, meeting PS in O. Alfo draw QR perpendicular to PS. Bifect PO in T. 18 Demonftrated with refpect to the earth,

It is demonftrated in the treatifes of conic fections, that PO is one half of the chord of the equicurve or ofculating circle drawn through the point P. Therefore PO is one half of the deflective chord of the planetary orbit. It is alfo demonftrated, that PR is one half of the parameter or *latus rectum* of the tranfverfe axis AB, or that it is the third proportional to AC and DC. Therefore PR or D r is of the fame conftant magnitude, in whatever part of the circumference the point P is taken.

It is evident that the triangles NSP, RPQ, and QPO, are all fimilar, by reafon 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 feen, that when a curve is defcribed by means of a centripetal force, fo that areas are defcribed 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 inverfely proportional to $C \times SN^2$. Therefore, in the elliptical motion of the planets, the forces are inverfely proportional to $L \times SP^2$; and fince L is a conftant quantity, the centripetal forces are inverfely proportional to SP^2, or to the fquares of the diftances from the fun.

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.

19 Obſerved in the motion of the moon, &c.

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 $\frac{v^2}{c}$, 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.

20 And demonſtrated in general terms.

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 Dd, Dδ be equal ſmall arches of the ellipſe and the circle. Join dS, δS. It is well known that DS is half of the chord of the equicurve circle at D, and therefore Dt 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 Dt. 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 Dt. Therefore the planet, if projected in the direction Dδ, 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 DSd, DSδ are deſcibed in the ſame time. But the baſes Dd, Dδ 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 DSd to the area DSδ 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.

21 All the planets retained in their reſpective orbits by one and the ſame force.

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

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.

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

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 elliptical motion round the earth.

23
How their regularity of the moon's motion

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.

24
May be calculated with precision.

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 mathesi 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,

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.

25 The secular equation of the moon's mean distance

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 planetary 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:

26 Deduced from the Newtonian law of planetary deflection.

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 $\frac{1}{179}$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 $\frac{1}{179}$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 $\frac{1}{179}$, 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 $\frac{3}{2}$ 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 $\frac{1}{179}$ of this velocity, multiplied by $\frac{3}{2}$ 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 ($\frac{2}{3}$ 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 diminution

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 0,00000001285. 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.

27 Certainty and utility of this law. 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.

28 Reciprocal deflection of the earth and moon, and of the ſun and planets, 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 equilibrio 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.* 29 Proved by the ebbing and flowing of the ſea,

30 And by different computations of the ſun's place in the 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 rectilineal 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 Keplerean 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.

31 Obſervations on the third law of motion.

32 Newton's extenſion of that law

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 ſtedfaſt 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.

33 Confirmed by obſervation.

The fortunate reſult of all this ſolicitude has been the complete eſtabliſhment of the Newtonian conjecture (for ſo 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 Keplerean 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 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 planets towards 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 result of such mutual action.

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 $\frac{1}{25000}$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 peculiarity explained 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 Oscillation of the planetary system.

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 Authenticity of the Indian aftronomy.

founded. It is very remarkable, that the periods which the Indians affign to thefe two planets, and which appeared fo inaccurate that they hurt the credit of the fcience of thofe ancient aftronomers, are now found precifely fuch as muft have obtained about three thoufand years before the Chriftian era; and thus they give an authenticity to that ancient aftronomy. The periods which any nation of aftronomers affign to thofe two planets would afford no contemptible mean for determining the age in which it was obferved.

The followiug circumftance is remarkable: Suppofe Jupiter and Saturn in conjunction in the firft 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 thefe three figns 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, Pifces, and Scorpio: then all begins again in Aries. It is highly probable that thefe remarkable periods of the oppofitions of Jupiter and Saturn, progreffive for 40 years, and ofcillating during 160 more, occafioned the aftrological divifion of the heavens into the four *trigons*, of fire, air, earth, and water. Thefe relations of the figns, which compofe a trigon, point out the repetitions of the chief irregularities of the folar fyftem.

39 Origin of the aftrological divifion of the heavens.

M. de la Place obferves (in 1796), that the laft difcovered planet gives evident marks of the action of the reft; and that when thefe are computed and taken into the account of its bygone motions, they put it beyond doubt that it was feen by Flamftead 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 difturbances of the folar fyftem. Their number is very great, and they go to all quarters of the univerfe: 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 inconfiderable. They remain but a fhort time in the neighbourhood of the planets, and they pafs 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 fatellites. They doubtlefs contribute, in general, to make the apfides of the planetary orbits advance.

41 They are affected by the planets.

On the other hand, the comets may be confiderably 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 defcribing ellipfes, or bodies which came but once into the planetary regions, and then retired for ever, caufed the aftronomers to confider this matter with great care. Halley had fhewn, in a rough way, that this comet muft have been confiderably affected by Jupiter. Their motion near the aphelion muft be fo very flow, that a very fmall change of velocity or direction, while in the planetary regions, muft confiderably affect their periods. Halley thought that the action of Jupiter might change it half a year. Mr Clairaut, by confidering the difturbing forces of Jupiter and Saturn through the whole revolution, fhewed that the period then running would exceed the former nearly two years (618 days), and affigned the middle of April 1759 for the time of its perihelion. It really paffed its perihelion on the 12th of March. This was a wonderful precifion, when we reflect that the comet had been feen but a very few days in its former apparitions.

A comet obferved by Mr Profperin and others in 1771 has greatly puzzled the aftronomers. Its motions appear to have been extremely irregular, and it certainly came fo near Jupiter, that his momentary influence was at leaft equal to the fun's. It has not been recognifed fince that time, although there is a great probability that it is continually among the planets.

42 Confequence of a comet and planet meeting.

It is by no means impoffible, nor highly improbable, that in the courfe of ages, a comet may actually meet one of the planets. The effect of fuch a concourfe muft be dreadful; a change of the axis of diurnal rotation muft refult from it, and the fea muft defert its former bed and overflow the new equatorial regions. The fhock and the deluge muft deftroy all the works of man, and moft of the race. The remainder, reduced to mifery, muft long ftruggle for exiftence, and all remembrance of former arts and events muft be loft, and every thing muft be invented anew. There are not wanting traces of fuch devaftations in this globe: ftrata 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 mutamur in illis.*

It is plain, that when we know the direction and the intenfity of the difturbing force, we can tell what will be the accumulated effect of its action for any time. The direction is eafily determined by means of the diftance: but how fhall we determine the intenfity? Since we fee that the whole waters of the ocean are deflected toward the moon, and have fuch 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 fun or a planet is greater or lefs in proportion to its quantity of matter. Newton indeed thought it unreafonable to fuppofe that a planet was deflected to the centre of the fun, which had no diftinguifhing phyfical property; and thought it more probable that the deflection of a planet to the fun was the accumulated deflection of every particle in the planet to every particle in the fun. But he was too fcrupulous to take this for granted. He therefore endeavoured to difcover what would be the fenfible deflection of one fphere to another, when each confifted of matter, every particle of which was deflected to every particle of the other with an intenfity inverfely proportional to the fquare of the diftance from it. By help of a moft beautiful and fimple procefs, he difcovered, that the tendency of a particle of matter to a fpherical furface, fhell, or folid, of uniform denfity at equal diftances from the centre, was the fame as if all the particles in the furface, fhell, or folid, were united in its centre: hence it legitimately followed, that the mutual tendency of fpherical furfaces, fhells, or folids, was proportional to the quantities of matter in the attracting body, and inverfely as the fquare of the diftance of their centres; and thus the law of attraction, competent to every particle of planetary matter, was the fame with that which *was obferved* among fpherical bodies confifting of fuch matter. And it is remarkable, that the inverfe duplicate ratio

43 Tendency of fpherical bodies towards each other directly as the quantity of matter, and inverfely as the fquare of the diftance of their centres.

tio 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 favours 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 neigbourhood of a great and ſolid mountain, ſenſibly deviated from the true vertical, and was deflected toward the mountain.

44 Proportional quantities 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 *(cæteris 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 planet. 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 $\frac{1}{100}$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 $\frac{1}{70}$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.

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

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!

Jam dubios nulla caligine prægravat error;
Queis ſuperum penetrare domos atque ardua cœli
Scandere ſublimis genii conceſſit acumen.

HALLEY.

46 Progreſs of Newton's diſcovery

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 $\frac{1}{2500}$th of 16 feet in a ſecond; and the moon ſhould deflect

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 $\frac{1}{110}$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 curvelineal 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
47 The universal law of gravitation,
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 $\frac{1}{25}$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 rectilineal motion, is in the inverse duplicate ratio of the distance. 48 Which is the ultimatum of his philosophy.

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. 49 Objections to the law of gravitation ill-founded.

The

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. 50 Our knowledge of that law ſatisfactory. 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.

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 interdict of natural imperfection. We would take a microſcope to look at light; we would *know* what *knowing* is, and we would *weigh heavineſs.*

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, ὥσπερ ψυχαι, which 51 Vain attempts to account for it. 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 ὥσπερ ψυχη in the Monad is nothing but an aukward 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. 52 Inconſiſtency of ſome of theſe accounts with the phenomena.

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. It

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.

54 Examined by Newton. 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.

55 Hypothesis of Leibnitz. This gentleman published in the Leipsic 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.

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 planet 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 rectilineal 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 solicitation 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 celiberrimo Isaaco Newtono, licet non possim judicare quomodo ad eam pervenerit.* This is really somewhat like impudence. — 56 Disingenuity of the author.

The *Principia* were published in 1686. They were reviewed at Leipsic, 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.

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 Leipſic 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 Mechanique*, 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.

58 Ether of Newton ſolves no difficulties.

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 recurred 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.

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.

59 Our notion of impulſe not clearer than of gravitation.

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

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.

60 Impulſe rarely obſerved.

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.

61 Intervening fluids mually difficulties.

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

 theory

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; because 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 aud 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.

63 Depends on the law of planetary deflection,

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 accumulation 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.

64 And evinces the wisdom of the Creator.

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!
"Unspeakable, 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. Lost, b. v.

"But wandering oft, with brute unconscious gaze,
"Man marks not THEE, 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.

65 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.

66 Discovery of Dr Herschel relating to it.

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

angle ſubtended by the ring at the mean diſtance from the earth is $46\frac{2}{5}''$. Therefore its elongation is $23\frac{1}{5}'$. 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 Keplerean 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. $32\frac{1}{4}'$ 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.

67
Its probable conſiſtency

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.

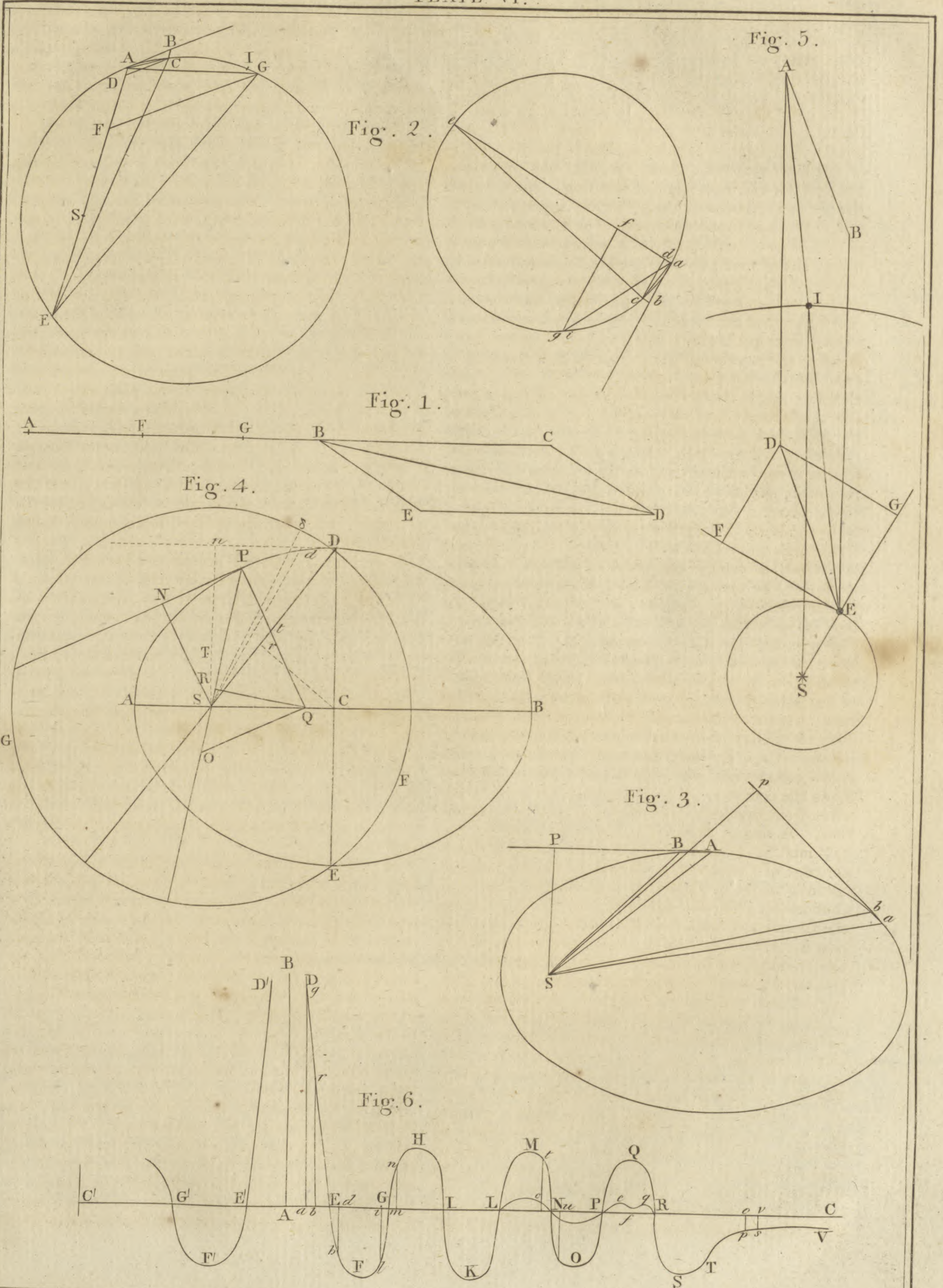
Such a ring or rings muſt have an oſcillatory motion round the centre of Saturn, in conſequence of their mutual action, and the action of the ſun, and their own irregularities: but there will be a certain poſition which they have a tendency to maintain, and to which they will be brought back, after deviating 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, preſerring its former momentum, and the limit will approach the axis; becauſe a greater velocity produces a greater centrifugal force, and requires a 68
greater gravitation to balance it. Such an atmoſphere And origin.
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. 69

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

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 $\frac{59}{63}$ 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 $\frac{1}{2500}$ 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



D. Lizars sculpt

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-glaſs 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 $\frac{1}{2500}$, 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 conſtitu-
70 Probable reaſon why we ſee no atmoſphere about the moon.
tion 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 $\frac{1}{70}$th of the earth, this limit will be about $\frac{1}{9}$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 earth: 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 torſêre ſophorum,
Quæque ſcholas hodie rauco certamine vexant,
Obvia conſpicimus, nubem pellente Matheſi.
Surgite mortales, terrenas mittite curas,
Atque hinc cæligenæ vires dignoſcite mentis,
A pecudum vitâ longe lateque remotæ.

Aſtrothemata || Aſymmetry.

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

ASTROTHESIA, 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.

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

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 ſurrounding 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 depoſite 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 governor 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, inſomuch 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 fuſees they were not frightened, but returned inceſſantly to the charge; ſo that finding our powder waſted 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 baſon 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 baſon, and winding round it with a number of ſinuoſities, exhibit a hundred groves, which are naturally variegated, and each more agreeable than another. Auteniqua.

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 monſoon 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

Automaton

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° 30′ and 34° 50′ of ſouth latitude, and between 20° and 23° 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 mechanician 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 exhibiter; 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 Freidrick 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 exhibiters. 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 exhibiter, 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.

Automaton, Axis.

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.

B.

Bahrdt.

BAHRDT (Dr Carl Friedirich) 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.

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

Carl Friedirich Bahrdt was, in 1741, born at Leipſig, 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. 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 Godschusky) 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 accquainted 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 Bahrdt, but it was sufficient to blast his character in Leipsig, 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 Godschusky to meet them in another house to receive the 200 dahlers due to her by Bahrdt; but when she was ushered into the room, and found no person waiting for her but Bahrdt'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 Bahrdt 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."

Bahrdt, 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 Godschusky 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 Bahrdt 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 Leipsig.

Bahrdt. 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 Bahrdt 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 Bahrdt, 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 satirical 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 Ersurth, 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 Basedow, 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, Bahrdt. ries, his aim being to form the young mind to the love of mankind and of virtue, by a courfe of moral education certainly fpecious, and apparently unexceptionable. To make this novel inftitution the more extenfively ufeful, the rules by which the education was to be conducted were framed in fuch a manner as, it was thought, would remove from the minds of Catholics, Lutherans, and Calvinifts, all uneafinefs refpecting the faith of their children, as it related to thofe particular tenets which feparated them into different communions. It was even propofed to banifh from the philanthropine all *pofitive* religion whatever, and to inftruct the youth educated there in the principles only of natural, or, as it was called, *philofophical religion*.

This plan was peculiarly fuited to Bahrdt's tafte, becaufe it left him at liberty to introduce into his academy any fyftem of religious or irreligious opinions that he pleafed; a liberty of which he refolved to avail himfelf, and, though now a doctor in theology, to outftrip, in licentioufnefs, 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 fimple. "The leading propenfities of the human mind (he fays) are three; inftinctive liberty, inftinctive activity, and inftinctive love." By thefe expreffions we fuppofe he means, "innate *love* of liberty, inftinct prompting to action, and the fexual appetite:" and he immediately adds, that "if a man is obftructed in the gratification of any of thefe propenfities, he fuffers an injury. The bufinefs therefore of a good education is to teach us how they are to be gratified in the higheft degree."

That fuch an education would be approved of by the uncorrupted natives of Switzerland was hardly to be expected; and Bahrdt foon found his fituation at Marfchlins as uncomfortable as it had been at Gieffen. "The Grifons (he fays) were a ftrong inftance of the immenfe importance of education. They knew nothing but their handicrafts; and their minds were as coarfe as their perfons." He quarrelled with them all, and was obliged to abfcond after lying fome time in prifon.

From Marfchlins he went to Durkheim, a town in the Palatinate, where his father had been minifter, and where his literary talents were well known. After fome little time he got an affociation formed for erecting and fupporting a *Philanthropine* or houfe of education. A large fund was collected; and he was enabled to travel into Holland and England to engage pupils, and was furnifhed with proper recommendations.

In London he gained the friendfhip of a clergyman, whom he reprefents as a perfon in the higheft degree accomplifhed. "With found judgment (fays Bahrdt), great genius, and correct tafte, he was perfectly a man of the world. He was my friend, and the only perfon who warmly interefted himfelf for my inftitution. To his earneft and repeated recommendations I owe all the pupils that I got in England, and many moft refpectable connections; for he was univerfally efteemed as a man of learning and of the moft unblemifhed character. He was my friend, my conductor, and I may fay my preferver; for when I had not bread for two days, he took me to his houfe, and fupplied all my wants."

For fo much kindnefs the reader doubtlefs fuppofes that the heart of Bahrdt overflowed with gratitude; but if fuch be his opinion, he is a ftranger to the principles of thofe who have on the continent of Europe affociated for the purpofe of enlightening the world. This amiable man, whofe character is here fo juftly drawn, was afterwards depicted by the monfter whom he had faved from perifhing by hunger, as a wretch loft to all fenfe of fhame and decency, as an apoftate from the Chriftian faith, and as a notorious frequenter of the London brothels! Fortunately he was able to vindicate his character completely from this flanderous abufe, and to convict Bahrdt of having publifhed what *could not poffibly be true*. Bahrdt.

This ungrateful liar returned from England, and carried into execution his plan of the Philanthropine. The caftle of Count Leining Hartzburgh at Heidefheim, having gardens, park, and every handfome accommodation, had been fitted up for it; and in 1778 it was confecrated by a folemn religious feftival. But his old misfortunes purfued 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 fo far ftifle his vanity as to conceal that he was the author. Of thefe pieces fome were fhocking to decency, and others fo horribly injurious to the characters of the moft refpectable men in the ftate, that he was continually under the correction of the courts of juftice. It was hardly poffible for a man of letters to be in his company, and not fuffer by it; for it was his conftant practice to attribute every ftep which he took towards atheifm, to the force of the arguments urged by fome of his friends.

To be his friend, or to obtain his applaufe, was indeed fo great a misfortune, that when the reader fees any perfon celebrated by Dr Bahrdt, in the beginning of a book, for found fenfe, profound judgment, accurate reafoning, or praifed for acts of friendfhip to himfelf, he may be affured, that before the clofe of the book this man fhall be reprefented as having in private converfation convinced the author, that fome doctrine, cherifhed and venerated by all Chriftians, is a piece of knavifh fuperftition.

Dr Bahrdt had married, while at Gieffen, a woman with a fmall fortune: but fuch a ftranger was he to the delicacies of wedded love, fo loft indeed to all fenfe 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 alfo *naked*, toyed with her in the fight of all his pupils. It was his boaft that he held his opinions independent of all mankind, and was indifferent whether they procured him praife or reproach; but it appears from this fact, that he was equally regardlefs of the praife or cenfure which might be attached to his actions; for furely the groffeft hog that ever before him battened in the Epicurean fty would not have prefented fuch an exhibition to boys.

The confequence of all this was, that he was obliged to fly from Heidefheim, leaving his fureties in the Philanthropine to pay about 14,000 dahlers, befides debts without number to his friends. He was imprifoned at Dienheim; but being foon releafed, he fettled at Halle, where he funk to be the keeper of a tavern and billiard-table. His houfe became of courfe the refort and the bane of the ftudents in the univerfity, and he was obliged to leave the city. He had fomehow got money fufficient to purchafe a little vineyard, pleafantly fituated

Bahrdt. ted in the neighbourhood. This he fitted up with every accommodation that could invite the ftudents, and called it *Bahrdt's Ruhe* (Bahrdt's repofe); where he lived for two years, directing the operations of a fecret fociety called the German Union, for rooting out Superstition and Prejudices, and for advancing true Christianity.

With Bahrdt's qualifications for advancing the interefts of genuine Chriftianity, the Chriftian reader is already fufficiently accquainted; 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 fpawn of the fecret fociety of *Illuminati* (fee Illuminati in this Supplement); and that its object is to abolifh the religion of the gofpel, and to teach in its ftead the fatalifm of the Stoics. With this view Chriftianity is confidered in the union as a myftical fociety, and its Divine Founder as the grand mafter of a lodge! The apoftles Peter, James, John, and Andrew, were the elect, brethren of the *third* degree, and initiated into all the myfteries. The remaining apoftles were only of the *fecond* degree; and the feventy-two, of the *firft*: a degree into which ordinary Chriftians may be admitted, and prepared for farther advancement. The great myftery is, that J—— C—— was a naturalist, and taught the doctrine of a fupreme mind, the fpectator but not the governor of the world.

To propagate thefe impious and abfurd notions, Bahrdt publifhed many books of the moft antichriftian tendency, and fome of them calculated to make their readers fhake off all moral obligation. But the labours of the fociety were not confined to religion: it inculcated on its members the moft dangerous maxims of civil conduct: for, as we learn from Bahrdt himfelf, the objects at which the Union aimed were—*Advancement of fcience—a general intereft and concern for arts and learning—excitement of talents—check of fcribbling—good education*—liberty—equality—*hofpitality*—delivery of many from misfortunes—*union of the learned—and at laft—perhaps—Amen.*

What the meaning of this enigmatical conclufion is we can only guefs; and we agree with the real philofopher from whom we have taken this account, that our conjectures cannot be favourable. Bahrdt was a villain, and could be affociated only with villains, whofe affairs he managed with the help of an old man, who lived at bed and board in his houfe for about fix fhillings a-week, and difcharged the office of fecretary to the Union.

When he had toiled in this caufe near two years, fome of the fecrets of the Union tranfpired; his former conduct and his conftant imprudence made him fufpected; his affociated friends lodged informations againft him; his papers were feized; and he himfelf was fent to prifon, firft at Halle and then at Magdeburgh. After fomething more than a year's confinement, he was fet at liberty, and returned to his *Ruhe*, not, alas! to live at eafe, or to exhibit fymptoms of repentance, but to lie down on a fick-bed, where, after many months fuffering of increafing pain, he died on the 23d of April 1793, the moft wretched and loathfome victim of unbridled fenfuality.

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 feeds of native virtue, which are choaked in the heart by fuperftition and defpotifm. Dr Bahrdt affected to be the enlightener and reformer of the world; and affirmed that all the evils of life originated from defpotifm and fuperftition. "In vain (fays he) do we complain of the inefficacy of religion. All pofitive religion is founded on injuftice. No prince has a right to prefcribe or fanction any fuch fyftem; nor would he do it, were not the priefts the firmeft pillars of his tyranny, and fuperftition the ftrongeft fetters for his fubjects. He dares not fhow Religion as fhe is, pure and undefiled—fhe 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 oppreffors, and princes would vanifh from the face of the earth."

Therefore, without troubling ourfelves with the truth or falfehood of his religion of nature, and affuming it as an indifputable point, that Dr Bahrdt has feen it in this natural and fo effective purity, it is furely a very pertinent queftion, "Whether has the fight produced on his mind an effect fo far fuperior to the acknowledged faintnefs of the impreffion of Chriftianity 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 divifions which fo unfortunately alienate the minds of profeffing Chriftians from each other?" The account here given of Dr Bahrdt's life feems to decide the queftion.

But it will be faid that we have only related fo many inftances of the quarrels of priefts and their flavifh adherents with Dr Bahrdt. Let us view him in his ordinary conduct, not as the champion and martyr of illumination, but as an ordinary citizen, a hufband, a father, a friend, a teacher of youth, a clergyman.

When Dr Bahrdt was a parifh minifter, and prefident of fome inferior ecclefiaftical diftrict, he was empowered to take off the cenfures of the church from a young woman who had born a baftard child. By violence he again reduced her to the fame condition, and efcaped cenfure by the poor girl's dying of a fever before her pregnancy was far advanced, or even legally documented. On the night of the folemn farce of confecrating his Philanthropine, he debauched the maid-fervant, who bore twins, and gave him up for the father. The thing was not judicially proved, but was afterwards made fufficiently evident by letters found among his papers, and publifhed by one of his friends in the Union. Having fupported thefe infants, in a pitiful manner, for little more than a year, he caufed them to be taken away from their mother, during night, fome time in the month of February 1780; and they were found expofed, the one at Ufstein, and the other at Worms, many miles diftant from each other, and almoft 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 hufband, and his gratitude to his friend, we have already feen; and we fhall now fee his kindnefs and fidelity. After wafting the greateft part of his wife's little fortune, he was fo provoked becaufe her brother would not give him up the remainder, amounting to about L.110, that he ever afterwards treated her with the greateft cruelty, and exhibited her to contempt and ridicule in two infamous novels. At Halle he brought a miftrefs into the houfe, and committed to her the care of his family, confining his wife and daughter to their own apartment;

Bahrdt, 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 Bahrdt. 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 Bahrdt was a true diſciple of illumination; and though his torch was made of the coarſeſt materials, and ſerved only to diſcover ſights 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 depoſite 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, Bahrdt 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. Bailly.

His ſtudies were not confined to the abſtract ſciences; for he cultivated letters with ſucceſs. His eloges of Charles V. of Corneille, 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 Bastile, 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 *aurea 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 give 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 astronomer 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. *Hutton's Dictionary.*

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 sovereign 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

to

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 FICUS, *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-glass, broad window-glass, 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 Anycleus (XXXIX. 129.); Essay on Numismatic Palæography, *ib.* 223; Dissertation on two Samaritan Medals of Antigonus

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 Mohammedan 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 Præneſte, *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 Piece; 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 Lacedemonians. The 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 Duſſaulx, 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 more

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

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 unſought, 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 glorioufly 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 ſo 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 uſeleſs 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 ſight 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

Batavia.

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 embrasure*, 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 surrounded 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.

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 seriously 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 Bata-

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

Batavia. 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 pavonina* 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

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 abſtaining 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 reſpecting 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, amonſt others, with the mangoſteen, 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

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 aticle 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 *essos* 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 Gonsalva Velho, a Portuguese, yet its authenticity seems unquestionable. It is confirmed not only by several contemporary writers, and by Wagenseil, 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 discovey 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, 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 cruize 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: "*Primæ 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 Alphonsus V. prosecuted the design; and John, who succeeded him, followed the plan of Alphonsus, 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 expresly, "*Behaimeus non modo*, &c. Bœhm 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 Bœhm'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 Alphonsus 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 Allasavas, 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.

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 powerful 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).

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 hiftory, the inhabitants of Berea. They are highly commended in Scripture for their ready reception of the gofpel, upon a fair and impartial examination of its agreement with the Old Teftament prophecies. Sopater, a Berean, attended the apoftle Paul to Afia. Acts xvii. 10—13. and xx. 4.

Bereans, in modern church hiftory, a fect of Proteftant diffenters from the church of Scotland, who take their title from, and profefs to follow, the example of the ancient Bereans, in building their fyftem of faith and practice upon the Scriptures alone, without regard to any human authority whatever.

Doctrines.

The Bereans agree with the great majority of Chriftians, both Proteftants and Catholics, refpecting the doctrine of the Trinity, which they hold as a fundamental article of the Chriftian faith; and they alfo agree in a great meafure with the *profeffed* principles of both our eftablifhed churches refpecting predeftination and election, though they allege that thefe doctrines are not confiftently taught in either church. But they differ from the majority of all fects of Chriftians in various other important particulars. Such as,

1. Refpecting our knowledge of the Deity. Upon this fubject, they fay that the majority of profeffed Chriftians ftumble at the very threfhold of revelation; and, by admitting the doctrine of natural religion, natural confcience, natural notices, &c. not founded upon revelation, or derived from it by tradition, they give up the caufe of Chriftianity at once to the infidels; who may juftly argue, as Mr Paine in fact does in his Age of Reafon, that there is no occafion for any revelation or word of God, if man can difcover his nature and perfections from his works alone. But this, the Bereans argue, is beyond the natural powers of human reafon; and therefore our knowledge of God is from revelation alone; and that without revelation man would never have entertained an idea of his exiftence.

2. With regard to faith in Chrift, and affurance of falvation through his merits, they differ from almoft all other fects whatfoever. Thefe they reckon *infeparable*, or rather the *fame*; becaufe, they argue, God hath exprefsly declared, "He that believeth fhall be faved;" and therefore it is not only abfurd, but impious, and in a manner calling God a liar, for a man to fay, "*I believe* the Gofpel, but *have doubts* neverthelefs of my own falvation." With regard to the various diftinctions and definitions that have been given of different kinds of faith, they argue, that "there is nothing incomprehenfible or obfcure in the meaning of this word as ufed in Scripture; but that as faith, when applied to human teftimony, fignifies neither more nor lefs than the mere fimple belief of that teftimony as true, upon the authority of the teftifier: fo, when applied to the teftimony of God, it fignifies precifely the belief of his teftimony, and refting upon his veracity alone, without any kind of collateral fupport from concurrence of any other evidence or teftimony whatever." And they infift, that as this faith is the gift of God alone, fo the perfon to whom it is given is as confcious of poffeffing it, as the being to whom God gives life is of being alive; and therefore he entertains no doubts either of his faith or his confequent falvation through the merits of Chrift, who died and rofe again for that purpofe. In a word, they argue, that the Gofpel would not be what it is held forth to be, "glad tidings of great joy," if it did not bring full perfonal affurance of eternal falvation to the believer: which affurance, they infift, "is the prefent infallible privilege and portion of every individual believer of the Gofpel." Thefe definitions of faith, and its infeparable concomitant affurance, they prove by a variety of texts, which our room permits us not to quote.

3. Confiftently with the above definition of faith, they fay, that the fin againft the Holy Ghoft, which has alarmed and puzzled fo many in all ages, is nothing elfe but *unbelief;* and that the expreffion, that "it fhall not be forgiven, neither in *this world* nor that which is to come," means only, that a perfon dying in infidelity would not be forgiven, neither under the former difpenfation by Mofes (the then *prefent* difpenfation, kingdom, or government of God), nor under the Gofpel difpenfation, which, in refpect of the Mofaic, was a kind of future world or kingdom to come.

4. The Bereans interpret a great part of the Old Teftament prophecies, and in particular the whole of the Pfalms, excepting fuch as are merely hiftorical or laudatory, to be typical or prophetical of Jefus Chrift, his fufferings, atonement, mediation, and kingdom: and they efteem it a grofs perverfion of thefe Pfalms and prophecies to apply them to the experiences of private Chriftians. In proof of this, they not only urge the words of the apoftle, that "no prophecy is of any private interpretation," but they infift that the whole of the quotations from the ancient prophecies in the New Teftament, and particularly thofe from the Pfalms, are exprefsly applied to Chrift. In this opinion many other claffes of Proteftants agree with them.

5. Of the abfolute all-fuperintending fovereignty of the Almighty, the Bereans entertain the higheft ideas, as well as of the uninterrupted exertion thereof over all works in heaven, earth, and hell, however unfearchable by his creatures. "A God without election (they argue), or choice in all his works, is a god without exiftence—a mere idol—a non-entity. And to deny God's election, purpofe, and exprefs will in all his works, is to make him inferior to ourfelves." For farther particulars refpecting the Berean doctrines, we muft refer the reader to the works of Meffrs Barclay, Nicol, Brookfhank, &c.

Origin.

The Bereans firft affembled as a feparate fociety of Chriftians in the city of Edinburgh in autumn 1773, and foon after in the parifh of Fettercairn. The opponents of the Berean doctrines allege, that this new fyftem of faith would never have been heard of, had not Mr Barclay, the founder of it, been difappointed of a fettlement in the church of Scotland. A refpectable clergyman of the eftablifhed church has even hinted fomething to this purpofe in Sir John Sinclair's Statiftical Account, Vol. IX. p. 599. But the Bereans, in anfwer to this charge, appeal not only to Mr Barclay's doctrine,

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publifhed firft in the fecond volume of the American Tranfactions, and afterwards by Nicholfon in N° II. and III. of his Journal.

Bereans doctrine, 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.

Practice. 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 authorised, 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.

Bereans, Berkenhout.

Present state. It may not be improper to add to the above delineation of the principles and practice of the Bercans, 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 Bielfeldt, 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 1760, 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 Linguæ Botanicæ*; a book of great utility to all students of botany.

Having continued some years at Edinburgh, Mr Ber-

Berkenhout. 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 ‖ Bezout.

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 eleves 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 love

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 eleves.

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 chagrines, 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 $x^a \times \overline{b + d x^c}|^e$. 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 *fuſee* 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 fuſee 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 fuſee, 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 BUTTON 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; 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 cibis 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.

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 Peterſburgh; 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 Anan, 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'

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'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 4to 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 Jameſon, Blacklock. Jameson, formerly minister of the Episcopal 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 rhime 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 soils 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 Paradise 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 disease 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 repose, 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.

Of

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 darkſome 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, diſquietude, 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 diſquietudes 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 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, aud was one of the principal guides of the proprietors.

Blair.

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 deſerves

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ſerves to be mentioned particularly, becauſe, in his own opinion, it determined the bent of his genius towards polite literature. An eſſay Περι 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 Coleſſie 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 Canongate, 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 competition 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.

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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 Canongate 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 pro-

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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

which

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.

1 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."

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.

2 Its application to bleaching.

Ann. de 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 inconveniencies, which would have rendered this proceſs impoſſible to be 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 mean time 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.

Ann. de Chim. II. 158.

"After this laſt immerſion, it is neceſſary to plunge the cloth in ſour 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 water; 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 Liſle, 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 matraſs, 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. ceffary to compare with it. Mr Watt employs, in the fame manner, a folution 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 manganefe, formed in fmall cryftals, and containing but little extraneous matter, the proportions of the fubftances to be fubmitted to diftillation are the following: Six ounces of calx of manganefe reduced to powder; one pound of common falt, alfo reduced to powder; twelve ounces of concentrated fulphuric acid, or oil of vitriol; from ten to twelve ounces of water.

"When thefe materials are prepared, we muft carefully mix the oxide of manganefe with the common falt, and introduce the mixture into the diftilling veffel placed upon a fand bath: we muft then pour upon it the fulphuric acid, previoufly diluted (and of which the heat occafioned by its mixture with water is diffipated), and immediately apply to the mouth of the matrafs the tube which is to conduct the gas into the intermediate veffel.—It muft not be forgot, that in this operation the lutes require particular attention.

"The fize of the veffels fhould be fuch, that the diftilling matrafs may be about one-third empty; and, for the quantity above mentioned, the tub fhould hold 100 quarts of water; there fhould alfo be an empty fpace of about 10 quarts, in order that when the gas lodges itfelf in the cavities intended to receive it, the water may have a free fpace to rife in.

"Before the commencement of the operation, the pneumatic tub muft be filled with water. The mixture being made, the gas, which very foon begins to difengage itfelf, drives out the atmofpherical air which is in the apparatus; when it is judged that the atmofpheric air has paffed into the cavities, it is to be drawn off by means of a bent tube, which is to be introduced fucceffively under each cavity: to drive out the water which has entered into the tube, this laft is to be forcibly blown into. The operation is then fuffered to go on without fire until it is perceived that the bubbles come over but flowly: then a little fire is to be applied, which is not to be haftily increafed at the beginning, but may be gradually augmented, fo that at the end of the operation the matter may be brought to a boiling ftate. It is known to be nearly finifhed when the tube by which the gas is difengaged, and the intermediate veffel, become hot. When the gas is difengaged only in a fmall quantity, the fire may be withdrawn; and when the diftilling veffel retains but a gentle warmth, it is to be unluted, and warm water is to be poured upon the refidue, that it may remain in folution, and thereby be more eafily poured out.

"The operation is longer or fhorter according to the quantity of materials: with that above mentioned, it fhould laft five or fix hours; it is proper not to haften it, that a larger quantity of gas may be drawn off. A fingle perfon is able to manage feveral diftillations at the fame time; to each of which may be given much larger quantities of materials than thofe which have been pointed out.

"The intermediate veffel by degrees becomes filled with a liquor, which is pure, though weak, muriatic acid; neverthelefs, we may perform the operation feveral times without extracting it: but when it is fuppofed that there is not fufficient empty fpace, this acid is to be drawn off by means of a fyphon, and, when we have collected a fufficient quantity of it, it may be fubftituted for the mixture of vitriolic acid and common falt in the operation we have defcribed, if we have no other ufe to make of it. That there may pafs but a fmall quantity of muriatic acid, not oxygenated, the firft tube ought to form a right angle, or even an obtufe one, with the body matrafs.

"During the operation, the agitator muft be from time to time put in motion, to favour the abforption of the gas by the water; when it is finifhed, the liquor is of a proper ftrength to ufe in bleaching; or we may put a lefs quantity of water in the tub, and then dilute the liquor according to the proportion already mentioned.

"In this ftate of concentration, although the liquor has a pretty ftrong odour, it neverthelefs is not hurtful, nor even very unpleafant, to thofe who ufe it: it is, however, proper to conduct it into the troughs where the cloths are placed by means of wooden canals, which are to be connected with the faufet or tube which is at the lower part of the tub."—The following is a defcription of the apparatus:

Plate VII. fig. 1.

ABCD is a reverberatory furnace, having, on a line with B, many fmall openings in its circumference, to ferve as chimneys; within which, upon a fand-bath *a*, is placed a matrafs *b*, the neck of which ftands out above the furnace, running through the opening D; which is to be clofed with clay. The mouth F, of the neck of the matrafs, is clofed by a cork G, through the middle of which paffes a tube H, which forms a communication between the infide of the matrafs *b*, and the intermediate veffel K, where it alfo paffes through a cork I, which clofes one of the three openings of that veffel. 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 fo difpofed that it may be fitted in immediately after the mixture is made in the matrafs.

The intermediate veffel K is about an eighth part full of water; into it is plunged the tube of fafety L, to prevent danger from regurgitation. This tube ought to be fo high, that the weight of the water which enters into it, by the preffure of the gas, may be great enough to caufe the gas to pafs 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, fo that the gas may be emitted under the firft of the three wooden, or (if they can be procured) ftoneware, cavities, or receivers, which are placed in the infide of the tub, one above the other. O is a handle which ferves to turn the agitator E, the movement of which facilitates the combination of the gas with the water. P is a fpigot and faufet to draw off the liquor.

4 Method of bleaching.

It is neceffary to prepare the cloth by leaving it to foak for 24 hours in water, or, which is better, in fome old ley. Afterwards it fhould be fubmitted to the action of one or two good leys; becaufe all the colouring part which may be extracted by the leys would elfe, without any advantage, confume a part of that liquor, which it is important to be as fparing of as poffible. After this, the cloth is to be carefully wafhed; then it is to be placed in the troughs, without any part being preffed or confined, in fuch a manner that it may be thoroughly impregnated with the liquor which is to run

Bleaching. 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 liſts, 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: neverthleſs, 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 mangaueſe, 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 potaſs, 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.

5 Theory of bleaching.

It remains for us now to conſider whether the new diſcoveries in chemiſtry do not throw ſome rays of light 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 potaſs diſſolves about double its own weight of it; carbonat of potaſs 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.

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.

Irish Transf. 1789.

"By treating eight quarts more of the saturated ley in the same manner, I obtained a further quantity of the greenish deposite; 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 deposite 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.

"One measure of caustic mineral alkali, whose specific gravity was 1,053, dissolved nearly the whole, leaving only a white residuum. Bleaching.

"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 pounds of the following substances. *Irish Transf.* 1789.

One hundred lbs.	*Mineral Alkali.*
Crystallized soda	20 lbs.
Sweet barilla	24
Mealy's cunnamara kelp	3,437
Ditto desulphurated 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 $\frac{24}{100}$ 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*.

* *Ann de. Chim.* VI. 210.

7 Bleaching of wool and silk.

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†.

† 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.

8 New mode of whitening silk.

Before the silk is wound off the cocons 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 cocons, 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 cocons 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 spirit only which has been kept in vessels of glass, of tinned copper, or of pure tin. Leaden 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 cocons are kept immersed in water almost boiling. Upon this part of the process M. Baumé remarks, 1. That the dead cocons 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 spirit

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 potaſs, in order that the diſtillation may be afterwards performed in a copper alembic. A ſolution of potaſs 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 baſon 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 baſon 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 diſſipation of the nitric and muriatic acids. When the acid in the retorts is ſufficiently cooled, it is poured a ſecond time into the copper baſon, 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 Bleaching paper.

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 Mode of whitening old books,

"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

 print

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 or Large Snouted 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 Nimiquas*. 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*.

Plate VII.

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 unremitted 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

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-louse; to experiments on the respiration of catterpillars 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-louse 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 unremitted 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 developement 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 developement 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 developement 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, developement, 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 interdict 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

these differences; and he concludes with obfervations refpecting the induftry of infects. This work being of a popular nature, the author fpared no pains in beftowing upon it thofe ornaments of which it was fufceptible. The principles which he thus difcovered and explained, induced him to plan *a fyftem of moral philofophy;* which, according to his ideas, confifted folely in the obfervance of that relation in which man is placed, refpecting all the beings that furround him. The firft branch would have comprehended, various means which philofophy and the medical fcience have difcovered for the prevention of difeafe, the prefervation and augmentation of the corporeal powers, and the better exertion of their force: in the fecond, he propofed to fhew, that natural philofophy has a powerful tendency to embellifh and improve our mind, and augment the number of our rational amufements, while it is replete with beneficial effects refpecting the fociety at large. To manifeft the invalidity of opinions, merely hypothetical, he undertook, in the third place, to examine, whether there were not truths within the compafs of human knowledge, to which the moft fceptical philofopher muft be compelled to yield his confent, and which might ferve as the bafis of all our reafonings concerning man and his various relations. He then would have directed his attention to a firft caufe, and have manifefted how greatly the idea of a Deity and Supreme Lawgiver favoured the conclufions which reafon had drawn from the nature and properties of things: but it is deeply to be regretted that his health, impaired by inceffant labour, would not permit him to complete the defign.

His laft publication was the *Palingenefis*, which treats of the prior exiftence and future ftate of living beings.

Of his publications in natural hiftory, thofe deemed the moft excellent are, his Treatife on the beft Means of Preferving Infects and Fifh in Cabinets of Natural Hiftory; a Differtation on the Loves of the Plants; fundry pieces on the Experiments of *Spallanzani*, concerning the Reproduction of the Head of the Snail; a Differtation on the *Pipa*, or Surinam Tod; and different Treatifes 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 extenfive correfpondence with fome of the moft celebrated natural philofophers and others. Of this number were *Reaumur*, *De Geer* the Reaumur of Sweden, *Du Hamel*, the learned *Haller*, the experimental philofopher *Spallanzani*, *Van Swieten*, *Merian*, and that ornament of Switzerland the great *Lambert*. He entertained, however, the utmoft averfion to controverfy. He thought that no advantage to be obtained by it could compenfate for the lofs of that repofe which he valued, with Newton, as the *rem prorfus fubftantialem*. He never anfwered remarks that were made to the prejudice of his writings, but left the decifion with the public; yet, ever ready to acknowledge his errors, he was fincerely thankful to every one who contributed to the perfection of his works. He was ufed to fay that one confeffion, *I was in the wrong*, is of more value than a thoufand 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 laft 25 years of his life were fpent in the fame rural fituation where he had paffed the greater part of his early days; yet notwithftanding the purfuit of literature was his fupreme delight, he never refufed to fufpend his ftudies, when the good of his country feemed to demand his fervices.

He was chofen in 1752 member of the Grand Council in the republic of Geneva: and he affifted regularly at their deliberations till the year 1768, where he diftinguifhed himfelf by his eloquence; his moderation, united with firmnefs; by his good fenfe and penetration in cafes of difficulty; and by the zeal with which he endeavoured to reclaim his fellow-citizens to that ancient fimplicity of manners which had been fo conducive to the welfare of the ftate, and to the love of virtue, fo effential to the exiftence of genuine liberty. His conduct, in every cafe, was confiftent with his principles. He took no pains to accumulate wealth, but remained fatisfied with a fortune equal to his moderate wants, and to the exercife of his benevolence. The perfect correfpondence between his extenfive knowledge and virtuous deeds procured him univerfal efteem.

In the year 1788 evident fymptoms of an *hydrops pectoris* manifefted themfelves; and from this time he gradually declined. He fuftained his indifpofition with unremitted cheerfulnefs and compofure. After various fluctuations, ufual in that complaint, he died on the 20th of May 1793, in the 73d year of his age; retaining his prefence of mind to the laft moment, adminiftering comfort to furrounding friends and relatives, and attempting to alleviate the diftrefs of his difconfolate wife, in whofe arms he expired.

As a demonftration of the high value placed upon his labours and talents by the literati, we have only to remark, that he was member of moft of the learned focieties of Europe.

BOOK-KEEPING, is an art of which the importance is univerfally known; and as commonly practifed, it has been fufficiently explained in the Encyclopædia Britannica. But fince that ariticle 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 Briftol, accountant, who calls it the *Englifh fyftem of book-keeping;* and thinks that by it accounts may be more regularly kept, and errors in accounts more eafily detected, than by any other method hitherto known. We are much inclined to be of his opinion; and fhall therefore lay before our redears his defcription of this method, as we find it in the fpecification of the patent which was granted to him January 26. 1796.

The Englifh Syftem of Book-Keeping requires three books, called a *day-book* or *journal*, an *alphabet*, and a *ledger*, which muft be ruled after the following method, *viz.* the day-book to have three columns on each page, for receiving the amount of the tranfactions; 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 muft alfo be on each page of the day-book four other columns ruled, two

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: 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.

But 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

Book-keeping, Boscovich.

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 ſo 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 condiſciples 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 publiſhed 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 logiſtic 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 Stay, 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 inertiæ* 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 pass 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 sorceries 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 negociation, 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

Bofcovich. and with this defire he complied cheerfully on many accounts. His fuccefs at London was equal to that at Vienna. He pleaded the caufe of his countrymen effectually there, and that without giving any offence to the French, with whom Ragufa foon after entered into a treaty of commerce.

Bofcovich came to London the more willingly, as he was defirous of converfing with the learned men of Britain. He was received by the prefident and principal members of the Royal Society with great refpect; and to that great body he dedicated his poem on the eclipfes of the fun and moon, which was printed on this occafion at London, in the year 1760. This is one of his works on which he himfelf put the greateft value, and it has been much efteemed by the learned. An edition of it was publifhed at Venice the year following, and a third at Paris, which is the moft correct: a tranflation of it into French has likewife been publifhed at Paris. In this very elegant Latin poem he gives an exact compend of aftronomy, which ferves as an introduction to the fubject; he then explains all that belongs to the doctrine of eclipfes, and their ufe in geography; he confiders the phenomena that are obferved in the eclipfes of the fun, and likewife of the moon; he propofes a theorem, which is his own, concerning the diftribution of light refracted from the atmofphere of the earth by the fhadow of the moon, which happens in the lunar eclipfes; he explains the phenomenon of the reddifh colour which often appears in the moon when fhe is eclipfed, of which a fufficient 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 occafion to give a clear idea of the principal confequences of the faid theory. All this is clothed with a beautiful poetical drefs, and is adorned with pleafant epifodes, not to mention the learned annotations which are fubjoined. This poem was compofed, for the moft part, whilft the author was in journeys, or by way of amufement, when he was obliged to wait for the opportunities of making aftronomical obfervations.

The fellows of the Royal Society invited Bofcovich to accompany fome of their number to America, to obferve the tranfit of Venus, which was to happen in the year 1762; but being otherwife engaged, he could not accept of that invitation. He intended, however, by all means to obferve that remarkable phenomenon, and had fixed on Conftantinople as a proper place for doing fo. He was conducted thither in a Venetian man of war, and much honoured by one of the baylos of that republic, who commanded the veffel; but, to his great regret, they arrived too late. He returned, by land, in the company of the Englifh ambaffador; and a relation of that journey was publifhed in French and afterwards in Italian.

During thefe journeys, Bofcovich's place in the Roman College was well filled by fome of thofe whom he himfelf had trained up in mathematical learning. He was now called by the fenate of Milan to teach mathematics in the univerfity of Pavia, with the offer of a very confiderable falary. He and his fuperiors thought proper to accede to this propofal, and he was received without being fubjected to any previous examination; which was always obferved, excepting in fuch an extraordinary cafe, by the decrees of the univerfity. Here he taught, with great applaufe, for the fpace of fix years, having at the fame time the care of the obfervatory of the Royal College of Brera. About the year 1770, the Emprefs Queen made him profeffor of aftronomy and optics in the Palatine fchools of Milan; requiring of him, however, that he fhould continue to improve the obfervatory of Brera; which, under his direction, became one of the moft perfect in Europe. Bofcovich.

Here he was extremely happy, teaching the fciences, applying to his favourite ftudies, and converfing and correfponding with men of learning and of polifhed manners; when an event happened which caufed to him the moft fenfible affliction. In the year 1773, the fociety to which he belonged, and to which he had been from his youth warmly attached, was, to his great regret and difappointment, abolifhed. They who had been Jefuits were allowed no longer to teach publicly; nor was there any exception made in favour of Bofcovich, neither (fuch was his humour then) would he have accepted of it, though it had been offered him. Propofals were made to him by feveral perfons of diftinction: and, after fome deliberation, he chofe Paris for his place of abode; to which he was induced by the circumftance of his being intimately acquainted with the prime minifter at that court. He had not been many months at Paris when the univerfity of Pifa fent him an invitation to go thither, in order to profefs aftronomy. But the French minifter, underftanding this, declared to the minifter of Tufcany, that it was the intention of his moft Chriftian majefty to make his dominions agreeable to Bofcovich, by giving him liberal appointments. In fact he was foon naturalized, and two large penfions were beftowed on him: the one as an honourable fupport, to the end that he might profecute his fublime ftudies at his eafe and in affluence; the other as a falary annexed to a new office, created in his favour, under the name of *Director of Optics for the Sea Service*, and with the fole obligation of perfecting the lenfes which are ufed in achromatical telefcopes.

At Paris he remained ten years, applying principally to optics, and much regarded, not only by the moft reafonable men of letters, but likewife by the princes and minifters, both of France and of other nations. But the greateft men are not exempt from being envied. Some of the French were difpleafed that a foreigner fhould appear fuperior to themfelves; others of them could not forget that Bofcovich had difcovered and expofed their miftakes. The irreligion which prevailed too much among thofe who bore the name of philofophers, was difagreeable to him. Thefe, and other fuch circumftances, made him wearied of Paris, and he defired to revifit his friends in Italy; for which purpofe he obtained leave of abfence for two years.

The firft place in Italy in which he made any ftay was at Baffano, a town in the territories of Venice. Here, mindful of his obligations, he printed what he had been preparing for the prefs during his ftay in France; and this compofes five volumes in large octavo, and is a treafure of optical and aftronomical knowledge. The fubjects treated of in thefe volumes are as follow: A new inftrument for determining the refracting and diverging forces of diaphanous bodies; a demonftration of the falfehood of the Newtonian analogy between light and found; the algebraic formulæ regarding the focufes of lenfes, and their applications for calculating the fpheri-

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 micrometical 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. Boſcovich.

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 numberleſs

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:

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. Academiarum. Socio
Qui. In. Soc. Jeſu. Cum. Eſſet. 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. Reddundæ
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. Suæ. Superſtes
Lutetiæ. Pariſiorum. Inter. Galliæ. Indigenas. Relatus
Commiſſum. Sibi. Perficiundæ. In. Uſus. Maritimos.
Opticæ. Munus. Adcuravit
Ampla. A. Ludovico. XV. Rege. Xmo. Attributa. Penſione
Inter. Hæc. Et. Poeſim. 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. Reviſens. Jam. Senex
Cum. Ibi. In. Elaborandis. Edendiſque. Poſtremis. Operibus
Plurimum. Contendiſſet. Et. Novis. Inchoandis. Ac. Veteribus. Abſolvendis
Seſe. Adcingeret
In Diuturnum. 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. Suam. Eidem. Sæpe. Probaverit
In. Arduis. Apud. Exteras. Nationes
Bene. Utiliterque. Expediundis. Negotiis
Quodque. Sui. Nominis. Celebritate. Novum. Patriæ. Decus. Adtulerit
Poſt. Funebrem. 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 Litteratura Europea*; and another, in form of a letter, was directed by M. de la Lande to the Pariſian journaliſts, 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 Maccarcſe; 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 deduced. 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.

Boſcovich's Syſtem of Natural Philoſophy.

1 View of Boſcovich's ſyſtem of natural philoſophy.

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 inertiæ* 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 C'AC 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-

2 The whole theory expreſſed by a geometrical curve. Plate VI. fig. 6.

Boscovich's System of Natural Philosophy.

perpendiculars *a g*, *b r*, *d h*, the segments of the axis A *a*, A *b*, A *d*, are called *abscisses*, 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 abscis A *a* be lessened likewise beyond whatever limits; that if this abscis 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 I, 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 abscisses 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.

3
The simplicity of this curve proved.

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. *2dly*, 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. *3dly*, That to every *abscis* an *ordinate* correspond. *4thly*, That if we take equal *abscisses* on each side of A, they have equal *ordinates*. *5thly*, That the right line AB be an *asymptote*, the area BAED being asymptotical, and consequently infinite. *6thly*, 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 abscis x, and let it be made $x x = z$. Then let us take the values of all the abscisses 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. $+ f = \mathrm{P}$. 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, lest 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 $z^r + g z^{r-1} + h z^{r-2}$ &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 $\mathrm{P} - \mathrm{Q}\, f = o$, 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′, &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 $\mathrm{Q}\, y = o$; and therefore, because of $\mathrm{P} - \mathrm{Q}\, y = o$, it will be $\mathrm{P} = o$. But this will happen only in those points in which z will be one of the roots of the equation $\mathrm{P} = o$; 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 $\mathrm{P} = o$. Wherefore it will likewise be $\mathrm{Q}\, y = o$; but it will not be $\mathrm{Q} = o$, seeing there is no common root of the equations $\mathrm{P} = o$ and $\mathrm{Q} = o$: it must therefore be $y = o$, and the curve will cut the axis: and thus the second condition is satisfied.

Besides, whereas it is $\mathrm{P} - \mathrm{Q}\, x = o$, it will be $y = \frac{\mathrm{P}}{\mathrm{Q}}$. the abscis 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 abscis z, one only ordinate y will correspond. This is the third condition.

Again, whether x be assumed positive or negative, pro-

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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 M^1, M^2, M^3, &c. and the ordinates $'N^1, 'N^2, 'N^3$, &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 M_1, M_2, M_3, ſucceſſively for x, and N_1, N_2, N_3, &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 M_1, M_2, &c. N_1, N_2, N_3, &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 M_1, M_2, M_3, &c. being ſucceſſively put for x, the values of the ordinate y muſt ſucceſſively be N_1, N_2, N_3, &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.

Proofs of the theory.

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, 4

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sion, they proceed jointly with the common velocity 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. 1. 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 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.

7 Objections to this law answered.

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.

8 Impossibility of contact between bodies.

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.

9 Repulsive forces

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

Bofcovich's Syftem of Natural Philofophy. increafe beyond all limits, feeing the velocity of the incurring bodies may be increafed beyond all limits. It muft likewife be mutual, becaufe action and reaction are always equal, as may be proved by induction.

10 In extended atoms. From thefe repulfive forces Bofcovich deduces the inextenfion of his atoms: for this repulfion being common to all matter, muft caufe a perfect fimplicity in the firft elements of body. If thefe elements were extended, and confequently compounded of particles of an inferior order, thefe particles might poffibly be feparated, and then they might meet, and an abrupt paffage from one velocity to another might take place, which we have excluded from nature by induction, and by a pofitive argument.

Befides this, by rejecting the extenfion of the firft elements of matter, we get rid at once of all the difficulties arifing from continued extenfion in body, which have always perplexed the philofophers, and have never been fatisfactorily explained. If the elements of matter are extended, each of them may be divided *in infinitum*, and each part may ftill be divided *in infinitum*. Can this divifion 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 *fimple* of the fame kind? Thefe difficulties regard not fpace, which is no real being; but they would regard matter if it had continued extenfion. All thefe perplexities are removed by maintaining, as Bofcovich does, that the firft elements of bodies are perfectly fimple, and therefore inextended (A).

11 Attractive forces. With regard to the exterior attractive forces of our fyftem, there can be no queftion; feeing they conftitute univerfal gravity, the effects of which we fee and feel every day. But between the interior repulfive and exterior attractive forces we muft admit many tranfitions from repulfion to attraction, and from attraction back to repulfion, in infenfible diftances, which are indicated to us by cohefion, fermentation, evaporation, and other phenomena of nature. And thus we have given, in fhort, Bofcovich's proofs of his whole fyftem.

12 Objections to the fyftem anfwered. III. This fyftem has been well received by the learned in Europe, and has contributed much to render its author famous; yet many objections againft it have been propofed. Some are ftartled at the rejection of all immediate contact between bodies: and indeed Bofcovich is perhaps the firft of mankind who advanced that opinion; but he allows that bodies approach fo near to one another, as to leave no fenfible diftance between them; and his repulfive forces make the fame impreffion on the nerves of our fenfes as the folid bodies could do. And therefore this opinion of his, however new, is nowife contrary to the teftimony of our fenfes. He only removes a prejudice which was before univerfal.

Some fay, that they cannot even form an idea of an inextended atom, and that Bofcovich reduces all matter to nothing: but certainly extenfion is not neceffary for the effence of a *being*, as muft be allowed by all thofe who hold that fpirits are inextended. Becaufe all the bodies that fall under our fenfes are extended, we are apt to look upon extenfion as effential to matter: but this error may be corrected by reflection, and an idea of an inextended atom may be formed, by confidering the nature of a mathematical point, which is the limit of any two contiguous parts of a line.

Others again have faid, that if the elements of matter were void of extenfion, there would be no difference between body and fpirit. But the difference between body and fpirit does not confift in the having or not having extenfion; but in this, that the atoms of matter are endued with repulfive and attractive forces, which fpirit has not; and fpirit has a capacity of thought and volition which bodies have not.

We may here obferve, that among the ancients Zeno, and among the moderns Leibnitz, held, that the firft principles of matter are inextended points. But both held this opinion with the inconfiftency, that they maintained the continued extenfion of bodies, without ever being able to fhew how continued extenfion could arife from inextended elements.

It has been objected likewife, that our repulfive 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 anfwer is eafy. We obferve the effects, and take notice of them: for them we muft admit an adequate caufe, without being able to determine, whether that caufe is an immediate law of the Creator, or fome mediate inftrument that he makes ufe of for that purpofe.

Some are unwilling to give up the idea of motion occafioned by immediate impulfe: but can they fhow a good reafon why *fome diftance* may not occafion motion as well as *no diftance?* Thefe are the principal objections that have been made againft the Bofcovichian fyftem.

IV. Before we proceed to the explication of phenomena by means of our theory, we muft advert, that in the curve expreffing this theory, the abfciffes denote the diftances between the atoms that are under confideration; the ordinates give the prefent *force*, and the area between any two of thefe ordinates gives the fquare of the velocity generated between them; the arches are either repulfive or attractive, according as they fall upon the fame fide with the afymptotic curve EG, or on the oppofite fide. 13 Obfervations with regard to the curve

We muft, in the next place, confider the paffages from one fide of the axis to the other. Sometimes the paffage is from repulfion to attraction, at other times from attraction to repulfion. The firft are called *limits of cohefion*, becaufe a particle removed from that limit returns back to it; becaufe if it is removed to a greater diftance it is attracted back, and if it is removed nearer it is repelled back. The fecond are called *limits of noncohefion*; 14 Limits of cohefion, &c.

(A) If a particle of matter is not extended, in what refpect does it differ from a point of fpace? Says Bofcovich, it is endowed with attractive and repulfive forces. What is this *it* before it is thus endowed? Does it *then* differ from a point of fpace? We can form no notion of any fuch difference. But a point of fpace, confidered as an individual, is diftinguifhed from another individual only by its fituation; it is therefore immoveable, but matter is moveable. Have thefe forces, then, which make matter an object of fenfe, any fubftratum, any thing in which they are inherent as qualities? What are the things which thefe qualities diftinguifh from each other as individuals?

Boscovich's System of Natural Philosophy. *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.

15 Composition of bodies.

16 The system applied to account for

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.

17 Impenetrability,

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.

18 Cohesion,

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. 19 Extension,

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. 20 Figure,

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. 21 Density,

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. 22 Mobility,

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. 23 Gravity,

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 particles 24 Fluidity,

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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 parallelopipeds, 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.

26 Softneſs, flexibility, and elaſticity.

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.

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.

30 Fire and fuſion, &c.

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.

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.

31 Light.

Boſcovich holds, that light is an *effluvium*, emitted with great velocity from the luminous bodies by a ſtrong repulſion. He explains all the moſt remarkable properties of this extroardinary 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.

32 Electricity and magnetiſm.

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.

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.

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.
34 Reconciliation of this with other systems, 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.

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."
35 Especially that of Newton. 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 inertiæ*, 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. 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 Ragusan.

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. 36 Comparison of this system to the key of a cypher.

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. 37 Existence of God.

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. 38 The world cannot be the effect of chance;

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

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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.

39 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, expresly designed for us by that Supreme Being. This evidently demands from us the highest degree of gratitude, love, and obedience.

Boshmen.

42 Revelation.

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 Boscovich 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.

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. *Boshmen* 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 Boshmen, therefore, far from being a distinct species, are only a promiscuous assemblage of mulattoes, negroes, and mastizos, of every species, and sometimes of Hottentots and basters (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 *Boshmen* 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 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

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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.

Bofwell.

that his practice there was not fo fuccefsful as it had been in his own country. He enjoyed, however, more completely than he could do in Edinburgh, the converfation of the great, the wife, the witty, and the good; and fuch converfation he always valued above wealth. He frequently vifited his native country, and efpecially Auchinleck, the feat of his anceftors; and foon after his return from one of thofe vifits he was feized with a diforder which proved fatal, on Tuefday the 19th of May 1795.

Such were the principal events in the life of Mr Bofwell. Of his character, it would be difficult to fay *much more* than he has faid himfelf in his "Journal of a Tour to the Hebrides;" and which may, with fome propriety, be copied here:

"I have given a fketch of Dr Johnfon. My readers may wifh to know a little of his fellow-traveller. Think, then, of a gentleman of ancient blood; the pride of which was his predominant paffion. He was then in his 33d year, and had been about four years happily married. His inclination was to be a foldier; but his father, a refpectable Judge, had preffed him into the profeffion of the law. He had travelled a good deal, and feen many varieties of human life. He had thought more than any body fuppofed, and had a pretty good ftock of general learning and knowledge. He had all Dr Johnfon's principles, with fome degree of relaxation. He had rather too little than too much prudence; and his imagination being lively, he often faid things of which the effect was very different from the intention. He refembled fometimes

'The beft good man, with the worft-natur'd mufe.'

"He cannot deny himfelf the vanity of finifhing with the encomium of Dr Johnfon, whofe friendly partiality to the companion of this tour, reprefents him as one 'whofe acutenefs would help my inquiry, and whofe gaiety of converfation, and civility of manners, are fufficient to counteract the inconveniences of travel, in countries lefs hofpitable than we have paffed.'

Few of Mr Bofwell's friends, we believe, could add much to this candid confeffion. His enemies, if he had any, might dwell upon his failings; but his failings were few, and injurious to no perfon. In his character good nature was predominant. He appeared to entertain fentiments of benevolence to all mankind, and to be incapable of *intentionally* injuring a human being. His converfation-talents were always pleafing, and often fafcinating. But can we wonder at this in him who, with a capacity to learn, had been the companion of Johnfon for more than 20 years? His attachment to the Doctor for fo long a period, was a meritorious perfeverance in the defire of knowledge. To it the world is indebted for the moft finifhed picture of an eminent man that ever was executed. We know there are objections to the *mode* of giving the life of Johnfon. It has been thought that ignorance has been wantonly expofed, and the privacy of focial life endangered. We fhall not enter deeply into this queftion. All that we can certainly affirm is, that the work has been read with avidity and pleafure; and that he who does not wifh to read it again may be fufpected to be deficient in tafte and in temper.

Mr Bofwell has been accufed of vanity; but when this accufation is brought againft him, it fhould not be forgotten that he enjoyed advantages which rendered that confpicuous in him from which no man can claim an exemption. We know not the man who would not have been vain to poffefs fo much of Dr Johnfon's converfation, and proud to give it to the world, in hopes that he who venerated Johnfon 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 himfelf during the laft two or three years of his life; and he flew for relief where perhaps it is beft to be found, to the fociety of the learned and the gay. Here, as he confeffes, 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 unfhaken," and his religious impreffions deep, and recurring frequently, let us hope that he has now attained that ftate from which imperfection and calamity are alike excluded.

Botany bay, Bouguer.

BOTANY-BAY. See *New Holland*, Encycl.; and *New South Wales* in this Supplement.

BOUGUER (Peter), an eminent mathematician and mechanical philofopher, was born at Croific, in Lower Bretagne, on the 10th of February 1698. His father John Bouguer, who was likewife a confiderable mathematician, was then profeffor royal of hydrography at that port; and under him young Bouguer ftudied mathematics, and the application of them to fhip-building, almoft from the period when he began to fpeak; fo that he was a proficient in thefe fciences before he had reached beyond the years of childhood. He was, however, removed from Croific to the Jefuits college at Vannes, where, at 13 years of age, he triumphed, in a public conteft, over a profeffor of mathematics, who had advanced a mathematical propofition erroneoufly. Two years after this he loft his father, whom he was appointed to fucceed in the office of hydrographer, after being publicly examined, and giving the moft complete proof of his being duly qualified to fill the vacant chair. He was indeed qualified by prudence as well as by fcience; for however furprifing 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 fucceffively propofed by the Academy of Sciences for effays on the beft way of equipping fhips with mafts, on the beft method of obferving at fea the height of the ftars, and on the moft advantageous way of obferving the declination of the magnetic needle or the variation of the compafs. In 1729 he publifhed an *Optical Effay upon the Gradation of Light*, in which he examined the intenfity of light, and determined its degrees of diminution in paffing through different pellucid mediums, and particularly in traverfing the earth's atmofphere. Of this effay, which was written upon a fubject that till then had not attracted the attention of philofophers, the reader will find fome account in the *Encyclopædia Britannica*, under the title Optics, n° 32, &c.

In 1730 Bouguer was removed from the port of Croific to that of Havre. In 1731 he obtained, in the Academy of Sciences, the place of affociate geometrician, vacant by the promotion of Maupertuis to that of penfioner; and in 1735 he was promoted to the office of penfioner-aftronomer. The fame year he was fent on the commiffion to South America, along with Meffrs Godin, Bouguer. Godin, Condamine, and Jeuffieu, to determine the meafure of the degrees of the meridian, and the figure of the earth. In this painful and troublefome bufinefs of ten years duration, chiefly among the lofty Cordelier mountains, our author, befides attending to the object of the voyage, made many fcientific obfervations; viz. on the effect of the Cordeliers on the polarity of the magnetic needle; on the expanfion and contraction of metals and other fubftances, by the fudden and alternate changes of heat and cold among thofe mountains; and on the refraction of the atmofphere from the tops of the fame, with the fingular phenomenon of the fudden increafe of the refraction, when the ftar can be obferved below the line of the level. He likewife afcertained the laws of the denfity of the air at different heights, from obfervations made at different points of thofe enormous mountains; he difcovered that the mountains have an effect upon a plummet, though he did not affign the quantity of that effect; he found out a method of eftimating the errors committed by navigators in determining their route; gave a new conftruction of the log for meafuring a fhip's way; and made feveral other ufeful improvements. M. Bouguer made at different times fome important experiments on the famous reciprocation of the pendulum; he invented in 1747 the Heliometer (fee that article *Encycl.*); and made many difcoveries relating to the intenfity of light (for which fee Optics-*Index*, Encycl.) His unremitting application to ftudy undermined his health, and he died on the 15th of Auguft 1758, in the 61ft year of his age.

Of his works which have been publifhed, the chief are, 1. The Figure of the Earth, determined by the Obfervations made in South America, 1749, in 4to. 2. Treatife on Navigation and Pilotage, Paris, 1752, in 4to. This work has been abridged by M. La Caille, in one volume 8vo, 1768. 3. Treatife on Ships, their Conftruction and Motions, in 4to, 1756. 4. Optical Treatife on the Gradation of Light, firft in 1729, then a new edition in 1760, in 4to.

His papers that were inferted in the Memoirs of the Academy are very numerous and important: as, in the Memoirs for 1726, comparifon of the force of the folar and lunar light with that of candles; 1731, obfervations on the curvilinear motion of bodies in mediums; 1732, upon the new curves called the *lines of purfuit*; 1733, to determine the fpecies of conoid, to be conftructed upon a given bafe which is expofed to the fhock of a fluid, fo that the impulfe may be the leaft poffible; determination of the orbit of comets; 1734, comparifon of the two laws which the earth and the other planets muft obferve in the figure which gravity caufes them to take; on the curve lines proper to form the arches in domes; 1735, obfervations 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 meafure of the degrees of latitude and longitude; 1739, on the aftronomical refractions in the torrid zone; obfervations on the lunar eclipfe of the 8th September 1737, made at Quito; 1744, fhort account of the voyage to Peru by the members of the Royal Academy of Sciences, to meafure 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 expanfion and contraction of metals by heat and cold; on the problem of the mafting of fhips; 1746, treatife on fhips, their ftructure and motions; on the impulfe of fluids upon the fore parts of pyramidoids, having their bafe a trapezium; continuation of the fhort account given in 1744 of the voyage to Peru for meafuring the earth; 1747, on a new conftruction of the log, and other inftruments for meafuring the run of a fhip; 1748, of the diameters of the larger planets; the new inftrument called a *heliometer*, proper for determining them, with obfervations of the fun; obfervation of the eclipfe of the moon the 8th of Auguft 1748; 1749, fecond memoir on aftronomical refractions, obfeved in the torrid zone, with remarks on the manner of conftructing the tables of them; figure of the earth determined by MM. Bouguer and Condamine, with an abridgment of the expedition to Peru; 1750, obfervation of the lunar eclipfe of the 13th December 1750; 1751, on the form of bodies moft proper to turn about themfelves, when they are pufhed by one of their extremities, or any other point; on the moon's parallax, with the eftimation of the changes caufed in the parallaxes by the figure of the earth; obfervation of the lunar eclipfe the 2d of December 1751; 1752, on the operations made by feamen, called *corrections*; 1753, obfervation of the paffage of Mercury over the fun the 6th of May 1753; on the dilatations of the air in the atmofphere; new treatife of navigation, containing the theory and practice of pilotage, or working of fhips; 1754, operations, &c. for diftinguifhing, among the different determinations of the degree of the meridian near Paris, that which ought to be preferred; on the direction which the ftring of a plummet takes; folution of the chief problems in the working of fhips; 1755, on the apparent magnitude of objects; fecond memoir on the chief problems in the working of fhips; 1757, account of the treatife on the working of fhips; on the means of meafuring the light.

Bouguer, Bread.

BREAD is fo effential an article of food that every ufeful method of making it fhould be generally known. Much has accordingly been faid on that fubject (*Encycl.*) under the titles Baking, Barm, Bread, and Yeast: but, fince the laft of thefe articles was publifhed, we have feen, in Dr Townfon's *Travels in Hungary*, a method of making bread at Debretzen; of which, as it may fometimes be adopted with advantage in this country, an account may, with propriety, be inferted here.

In the baking of this bread, a fubftitute is ufed for yeaft, 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 moiftened by it: to this are added four or five pounds of leaven; when this is only warm, the mafs is well worked together to mix the different parts. This mafs is then put in a warm place for 24 hours; and after that, it is divided into fmall pieces about the fize of a hen's egg, or a fmall orange, which are dried by being placed upon a board, and expofed to a dry air, but not to the fun; when dry, they are laid by for ufe, and may be kept half a year. This is the ferment; and it may be ufed in the following manner: For a baking of fix large loaves, fix good handfuls of thefe balls, broken into fragments, are taken and diffolved in feven or eight quarts of warm water. This is poured through a fieve into one end of the bread trough, and three quarts more of warm water are poured through the fieve after it, and what remains

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, 45½ 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 45½ 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 121½ lb. of meal, ſo that there was here but ½ 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*, 93½ lb. and of bran and pollard 25¼ lb.; ſo that he loſt, of two buſhels, but 2¼ lb. both in grinding and dreſſing. The offal, or bran and pollard, being dreſſed in a bolting mill, yielded as follows:

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: Let

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 Tweedale, for the saving of hops, and, at the same time, giving to the liquor, whether ale, beer, or porter, a superior flavour and quality.

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 hogsheads, 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 expands

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 piece 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. 80.); 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 enterprize 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 method, Brindley. method, which has been fucceſsfully practifed, of building fea-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 lofing and a gaining bucket.

The intenfity of application which all his various and complicated employments required, probably fhortened his days; as the number of his undertakings, in fome degree, impaired his ufefulnefs. He fell into a kind of chronic fever, which, after continuing fome years, with little intermiffion, 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 Tunhurft, in Staffordfhire, and was buried at New Chapel in the fame county.

In appearance and manners, as well as in acquirement, Mr Brindley was a mere peafant. Unlettered, and rude of fpeech, it was eafier for him to devife means for executing a defign than to communicate his ideas concerning it to others. Formed by nature for the profeffion he affumed, it was there alone that he was in his proper element; and fo occupied was his mind with his bufinefs, that he was incapable of relaxing in any of the common amufements of life. As he had not the ideas of other men to affift him, whenever a point of difficulty in contrivance occurred, it was his cuftom to retire to his bed, where, in perfect folitude, he would lie for one, two, or three days, pondering the matter in his mind till the requifite expedient had prefented itfelf. This is that true infpiration which poets have almoft exclufively arrogated to themfelves, but which men of original genius in every walk are actuated by, when, from the operation of the mind acting upon itfelf, without the intrufion of foreign notions, they create and invent.

A remarkably retentive memory was one of the effential qualities which Mr Brindley brought to his mental operations. This enabled him to execute all the parts of the moft complex machine in due order, without any help of models or drawings, provided he had once accurately fettled the whole plan in his mind. In his calculations of the powers of machines, he followed a plan peculiar to himfelf; but, indeed, the only one he could follow without inftruction in the rules of art. He would work the queftion fome time in his head, and then fet down the refult in figures. Then taking it up in this ftage, he would again proceed by a mental operation to another refult; and thus he would go on by ftages till the whole was finifhed, only making ufe of figures to mark the feveral refults 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 forts to form, he could not avoid that perplexity and embarraffment which a readinefs in the proceffes carried on by pen and paper can alone obviate. His eftimates of expence have generally proved wide of reality; and he feems to have been better qualified to be the contriver, than the manager of a great defign. His moral qualities were, however, highly refpectable. He was far above envy and jealoufy, and freely communicated his improvements to perfons capable of receiving and executing them; taking a liberal fatisfaction in forming a new generation of engineers able to proceed with the great plans in the fuccefs of which he was fo deeply interefted. 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 fmall number of mankind who form eras in the art or fcience to which they devote themfelves, by a large and durable extenfion of its limits.

Briffot. BRISSOT (J. P.), acted fo confpicuous 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 fuch a life, we believe it impoffible at prefent to give; for characters like Briffot's are almoft always mifreprefented 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 fubfided, the impartial truth is nowhere to be found.

In a fulfome panegyric, under the denomination of *The Life of J. P. Briffot*, faid to be written by himfelf, we are told, that he was born January 14. 1754; and that his father was a *traiteur*, or "the keeper of an eating-houfe," but in what place we are not informed. Our author, however, affures us that the old man was in eafy circumftances, and that he employed all the means refulting from them to give to his numerous family a good education. The fubject of this memoir was intended for the bar; but not relifhing the ftudies neceffary to fit him for the profeffion of the law, or, if we choofe to believe him, having a mind too *pure* and *upright* for the ftudy of *chicane*, he relinquifhed the purfuit after five years of drudgery!

To relieve his wearinefs and difguft, he applied himfelf, he fays, to literature and the fciences. The ftudy of the languages was above all others his favourite purfuit. Chance brought him acquainted with two Englifhmen on their travels through France: he learned their language; and this circumftance, he tells us, decided his fate.

"It was at the commencement of my paffion for that language (continues he) that I made the metamorphofis of a diphthong in my name which has fince been imputed to me as fo heinous a crime. Born the thirteenth child of my family, and the fecond of my brothers in it, I bore, for the fake of diftinction, according to the cuftom of Beauce, the name of a village in which my father poffeffed fome landed property. This village was called *Ouarville*, and Ouarville became the name by which I was known in my own country. A fancy ftruck me that I would caft an Englifh air upon my name; and accordingly I fubftituted, in the place of the French diphthong *ou*, the *w* of the Englifh, which has precifely the fame found." For this puerile affectation, which was certainly not criminal, he juftifies himfelf by the example of the literati of the 16th and 17th centuries, who made no fcruple of Grecifing and Latinifing their appellatives.

Having profecuted his ftudies for two years, he had an application from the Englifh proprietor of a paper then much in circulation, and intitled *Le Courier de l'Europe*. This man having drawn upon himfelf an attack from government, felt and yielded to the neceffity of printing his paper at Boulogne-fur-mer. It was his wifh to render it interefting to the French in the department of mifcellaneous intelligence; which he therefore wifhed to fubmit to the fuperintendency and arrangement of

Briffot.

of Briffot, who reprefents himfelf as for fome moments hefitating. The profeffion of a journalift, fubject to a licenfer, was repugnant to his principles; yet it fecured his independence, and put into his power the means of profecuting an inveftigation of conftitutions and of the fciences. After fome ridiculous reafoning from the original ftations of *Bayle*, *Poftel*, and *Rouffeau*, he at laft accepted of the employment, and became enamoured of it, "becaufe (fays he) it enabled me to ferve talents and virtue, and, as it were, to inoculate the French with the principles of the Englifh conftitution.

This employment, however, did not laft for any length of time. The plan of the proprietor of the *Courier* was overthrown by adminiftration, and Briffot quitted Boulogne to return to his firft ftudies. Having informed us of this fact, he makes an extravagant pretence to unfullied virtue, and calls upon the inhabitants of the city which he had left to bear witnefs, not only that he had *no vices*, but that he had not even the *feeds* of any one of the vices which his adverfaries, it feems, had laid to his charge.

"Doubtlefs (fays he), too eager to publifh 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 inftant of my beginning to reflect, againft religious and political tyranny, I folemnly protefted, that thenceforward I would confecrate my whole life to their extirpation. Religious tyranny had fallen under the redoubled ftrokes of Rouffeau, of Voltaire, of Diderot, and of D'Alembert. It became neceffary to attack the fecond;" and this was a tafk which the vanity of Briffot led him to confider as referved for him.

What Voltaire and his friends meant by religious tyranny, and how they conducted their attacks againft it, are matters, alas! too well known to all Europe; and as our author chofe thefe philofophers for his guides, we might infer, without much degree of miftake, what he underftood by political tyranny, and by what means he meditated its extirpation. But he has not left us to make this difcovery by inference.

"It became neceffary (fays he) to break in pieces the political idol, which, under the name of *monarchy*, practifed the moft violent defpotifm; but to attack it openly, was to expofe the affailant without the poffibility of ferving mankind. It was by a fide blow that it was to be wounded moft effectually;" and therefore he refolved to begin his operations by attacking fome of thofe abufes which might be reformed without apparently fhaking the authority of the prince.

Our readers, at leaft the fober part of them, will probably think that this mode of attack is not peculiar to Briffot, but that it has been practifed, or attempted to be put in practice, by afpiring demagogues in all ages and countries, who have uniformly begun their career of innovation by exciting the public mind againft thofe abufes in government, of which the exiftence cannot wholly be denied. The fubject to which our author thought fit to call the attention of his countrymen, was the criminal jurifprudence: a fubject, fays he, which, with the exception of fome particulars that had been fuccefsfully inveftigated by Beccaria and Servan, no writer had thoroughly confidered in a philofophical point of view. Thinking himfelf fully equal to this tafk, he drew up a general plan; and in the year 1780 publifhed his Theory of Criminal Laws, in two vols 8vo. This work, favourably received by foreigners, applauded by fome journalifts, and pulled to pieces by others, procured him the friendfhip of the warmeft advocates for human liberty, in whofe opinion the defects of his plan were highly pardonable, on account of the energy confpicuous in his remarks. This publication was foon followed by two difcourfes which gained the prize in 1782 at the academy of Chalons-fur-Marne; the one upon the reform of the criminal laws, and the other on the reparation due to innocent perfons unjuftly accufed.

It is natural to fuppofe that the government beheld with an evil eye thefe writings, which, under pretext of dragging into light the abufes of the criminal laws, infinuated dangerous principles on the nature of government in general.

His next work was intitled, *A Philofophical Library of the Criminal Laws*, in 10 vols; the true object of which was to difseminate in France thofe principles of liberty which guided the Englifh and the Americans in framing and expounding their laws.

But the ftudy of legiflation and politics had not entirely drawn him off from that of other fciences; fuch as chemiftry, phyfics, anatomy, theology, &c. Thefe he conftantly cultivated with ardour; but acknowledges that in each he met with obfcurities, and that in every quarter truth efcaped from his refearches. He therefore fat down to inveftigate the nature of truth, and the proper method of attaining to it in every department of refearch; and the refult of his labours was a kind of *novum organum*, by which he feems 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 propofed to inveftigate what is *certain* in knowledge and what *doubtful*, and then to ftrike the balance of the account.

He was prevented, however, from completing his plan, which he regrets exceedingly; for, as he affirms, with *becoming modefty*, his work would certainly have amended its readers! But the French government happened to think otherwife; his aim, which, he fays, was to lead mankind to reflect on their rights, was perceived, and he was accufed to the minifter as a feditious writer. The career of genius was ftopped by the dread of the Baftile; and he was obliged to take refuge in London. There it was his wifh to create *a univerfal confederation of the friends of liberty and truth*, and to eftablifh a *centre of correfpondence and union* with the learned and the politicians of Europe. This dark defign, however, was fruftrated by the treachery, as it would appear, of his affociates, who had bound themfelves, he fays, by the moft *facred oaths*, to affift him, and had offered to fign articles *even with their own blood*.

Finding himfelf unable to proceed directly to the object which he had in view, he refolved to *enlighten his* countrymen gradually, and to begin with exciting their love and admiration of the Englifh conftitution. That conftitution, which he had inveftigated on the fpot, appeared to him a model for thofe focieties which were defirous of changing their form of government. It was but little known, he fays, in France (the work of *De Lolme* being at that time only in the hands of the learned);

ed);

Briffot.

ed); and to make it known was to make it beloved, was to render it defired. But the French minifters ftood upon their guard, and it became neceffary to *deceive* them. He refolved therefore to bring forward a journal written actually in London, and profeffing to contain only a *defcription of the fciences and arts of England*, whilft the greater part of it was to be occupied in reality by an inveftigation of the *Englifh conftitution*.

After many difficulties, the miniftry granted a privilege for this journal, being publifhed in London, to be reprinted in Paris; and it firft appeared in 1784. "In the twelve numbers which have been publifhed (fays the author), the friends of liberty muft have perceived, that if, on the one fide, I endeavoured to inculcate more juft ideas than had hitherto been entertained concerning this celebrated ifland; fo, on the other, I refolutely made my advances toward that important end which has perpetually prefided over all my labours, *the univerfal emancipation of men*."

His affairs calling him at this time to Paris, he was arrefted and conveyed to the Baftile on the 12th of July 1784. In this conduct of the government we cannot perceive any thing very tyrannical or arbitrary, fince he confeffes, that, in the 16th page of the firft number of his Journal, he had fuffered the *fecret and favourite aim*, which always guided his pen, to become difcernible. He was, however, difcharged from prifon on the 5th of September, and returned with increafed zeal to his former employments.

"This perfecution (fays he), far from extinguifhing the ardour of my wifhes to inculcate the principles of freedom, ferved only to inflame it the more." Accordingly, in 1785, he publifhed two letters to the Emperor Jofeph II. *concerning the right of emigration, and the right of people to revolt*. The firft of thefe letters, which, though well known in Germany, were in France fuppreffed by the *police*, was occafioned by what the author calls the ridiculous and barbarous edict againft emigration; and the fecond by the punifhment of *Horiah* the chief of the *Walachian* infurgents. In this laft letter he lays it down as a maxim, that all people under fuch a government as that of the *Walachians*, have from nature a facred *right* to revolt, a right which they can and ought to exercife. In the fame fpirit he brought out, in 1786, his Philofophical Letters on the Hiftory 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 diftant, notwithftanding all his efforts to haften it, he refolved to leave France for the purpofe of fettling in America. His project received the approbation of feveral, whofe fentiments were congenial with his own. But as it was thought imprudent to tranfport numerous families to a country fo far off, without thoroughly knowing it, Briffot was engaged to proceed thither, to examine the different places, to obferve the inhabitants, and to difcover where and in what manner the eftablifhment they had propofed might be moft advantageoufly fixed. He had fome time before inftituted a fociety at Paris for accomplifhing the abolition of the negro trade, and for foftening the condition of the flaves. At the period of his departure, this fociety confifted of a confiderable number of diftinguifhed members, and he was commiffioned to carry the firft fruits of their labours to America. His ftay there, however, was not fo long as he was defirous 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 meafures and in thofe of his friends. This idea, added to other circumftances, accelerated his return. The fire had blazed forth in his native country. "Hope (fays he) animated every heart; the moft diftinguifhed champions had engaged in the conteft; I too became defirous to break a lance, and I publifhed my *Plan of Conduct for the Deputies of the People*."

Briffot, Brown.

This, and other works of a fimilar kind, of which he loudly boafts the merits, raifed him high in the favour of the republican part of the nation, and he became prefident of his diftrict; where he acted, according to his own account, with great uprightnefs in the municipality, in the firft committee of inquiries, and as an elector. At laft he became a member, firft of the *National Affembly*, and, after its diffolution, of the *Sanguinary Convention*; and by fome means or other got to be the leader of a party called fometimes the *Girondifts*, and fometimes the *Briffotines*. From that period the principal events of his life were involved with the public tranfactions of the nation, of which we have given an account in the *Encyclopædia* under the title REVOLUTION (fee that article, n° 101—182.) The Girondift faction was denounced by the Mountain, and Briffot fuffered by the guillotine on the 30th of November 1793. He fell indeed by a very unjuft fentence; but his fall was the natural confequence of that anarchical tyranny under which no man had contributed more than he to fubject his native country.

BROWN (Dr John), author of the *Elementa Medicinæ*, &c. was born in the village of Dunfe, or, as fome fay, Lintlaws, in the county of Berwick, in the year 1735-6. His parents were of mean condition, but much refpected 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 fhare towards the fupport of the family by the profits arifing from a milch cow.

Such were the perfons who, in an obfcure part of the country, gave birth to a fon deftined, at a future period, to make a diftinguifhed figure in the republic of letters; and from whom originated a fyftem of the animal economy, which, whatever be its real merits, has undoubtedly produced a confiderable revolution in the practice of medicine.

At the age of three or four years, young Brown was put to a reading fchool in Dunfe, which he himfelf 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 ftrength of mind for which he was afterwards fo eminently diftinguifhed. In the fhort period of a year he became able to read with facility any part of the Bible, and acquired over his clafs-fellows that fuperiority which he ever after maintained both at fchool and college.

It was almoft immediately after his entrance into this fchool, that his infatiable defire of reading commenced; and fo unremitting was his application, that he is faid never to have been found, even at thofe hours which children much more advanced in life devote to amufement, without a book in his hand.

While he was making this rapid progrefs in the rudiments

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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 *."

Dr Beddoes.

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, 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 diſmiſſion 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 the

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 Dunse; 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 enable 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

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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 negociation 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

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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 langour.

" 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

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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 chieftian, 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.

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'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 excess. 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 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

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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 maſter 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

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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 Sanſon; that neither Dr Shaw nor Sanſon 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 atchieved 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 Ruſſel 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 eſcurial; 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

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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 Cosseir 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 Masua; 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 those 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, 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 (ſays 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 about the ſource of the Nile as a violent effort of a diſtempered 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; and

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.

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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 $3\frac{1}{11}$ dwts. or ſomewhat more than $2\frac{1}{4}$ 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 Maſuah, 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 Maſuah. Arriving at Teawa the 21ſt March 1772, he had the misfortune to find the Shekh Fidele of Atbara, the counterpart of the Naybe of Maſuah 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 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.

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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 Marſeilles; by means of which noble inſtrument, now depoſited in the Muſeum at Kinnaird, 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 *hæreditas 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.

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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 Furſhout, 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 unſurmountable, Mr Bruce made no reply, though in converſation he ſaid he would do it in the ſecond edition of his book.

* Suppoſed to be Dr Rotheram, profeſſor of natural philoſophy in the univerſity of St Andrew's.

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 ſailed 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 harams 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

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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 negociation, 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 Masuah, 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.

Bruce, Buck-wheat,

After his return to his own country, he resided mostly at Kinnaird; 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 Petersburgh 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

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 ſuperintendence 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 indigenous 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

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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 Elewsis Bay, near the new settlement called Hesper Elewsis: 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 sort, 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, musk-melon, the pumpkin, tamarind, banana, and numbers of other delicious fruits, also flourish here. The adjoining territories produce many valuable sorts of spices, 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.

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" 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.

"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 acquainted, 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 Bellytore, 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;

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 senate, 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 period

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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 Dodsley, an eminent bookseller, a plan of an Annual Register of the civil, 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 ferments 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 consider,

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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 preſerved 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 woolpack."

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.

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 democrate.

About

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 democrate, 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 sound reasoning, and everyway 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, "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 bellowings 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 biassed 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.

Burke, Burnet.

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 Prospect 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,

Burnet. 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 county, 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. Burnet.

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 justiciary. 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 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 *pitting* 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 ingenious, 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.

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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 of

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of every Saturday and Sunday, these Psalms are sung in solemn family-devotion, a chapter of the Bible is read, and extemporary prayer is fervently uttered. The whole books of the Sacred Scriptures are thus continually in the hands of almost every peasant. And it is impossible that there should not be occasionally some souls among them, awakened to the divine emotions of genius by that rich assemblage which those books present, of almost all that is interesting in incidents, or picturesque in imagery, or affectingly sublime or tender in sentiments and character. It is impossible that those rude rhymes, and the simple artless music with which they are accompanied, should not occasionally excite some ear to a fond perception of the melody of verse. That Burns had felt these impulses, will appear undeniably certain to whoever shall carefully peruse his *Cottar's Saturday's Night;* or shall remark, with nice observation, the various fragments of Scripture sentiment, of Scripture imagery, of Scripture language, which are scattered throughout his works.

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 assemblage 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 search: 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.

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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 becocoming 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 fireside.

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

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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 copyright 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, the

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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 fimilar circumftances. He fuffered himfelf to be furrounded by a race of miferable beings, who were proud to tell that they had been in company with Burns, and had feen Burns as loofe and as foolifh as themfelves. He was not yet irrecoverably loft to temperance and moderation; but he was already almoft too much captivated with their wanton revels, to be ever more won back to a faithful attachment to their more fober charms. He now alfo began to contract fomething of new arrogance in converfation. Accuftomed to be among his favourite affociates what is vulgarly but expreffively called *the cock of the company*, he could fcarcely refrain from indulging in fimilar freedom and dictatorial decifion of talk, even in the prefence of perfons who could lefs patiently endure his prefumption.

The fubfcription-edition of his poems, in the mean time, appeared; and although not enlarged beyond that which came from the Kilmarnock prefs by any new pieces of eminent merit, did not fail to give entire fatisfaction to the fubfcribers. He was now to clofe accounts with his bookfeller 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 fpirit and fimplicity of manners, and boafted his refolution to return to the plough; yet ftill he lingered in Edinburgh, week after week, and month after month, perhaps expecting that one or other of his noble patrons might procure him fome permanent and competent annual income, which fhould fet him above all neceffity of future exertions to earn for himfelf the means of fubfiftence; perhaps unconfcioufly reluctant to quit the pleafures of that voluptuous town-life to which he had for fome time too willingly accuftomed himfelf. An accidental diflocation or fracture of an arm or a leg confining him for fome weeks to his apartment, left him during this time leifure for ferious reflection; and he determined to retire from the town without longer delay. None of all his patrons interpofed to divert him from his purpofe of returning to the plough, by the offer of any fmall penfion, or any finecure place of moderate emolument, fuch as might have given him competence without withdrawing him from his poetical ftudies. It feemed 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 profeffion; and that it became incumbent upon thofe patrons who had called him from the plough, not merely to make him their companion in the hour of riot, not fimply to fill his purfe with gold for a few tranfient expences, but to fecure him as far as was poffible from being ever overwhelmed in diftrefs in confequence of the favour which they had fhown him, and of the habits of life into which they had feduced him. Perhaps indeed the fame delufion of fancy betrayed both Burns and his patrons into the miftaken idea, that, after all which had paffed, it was ftill poffible for him to return in cheerful content to the homely joys and fimple toils of undiffipated rural life.

In this temper of Burns's mind, in this ftate of his fortune, a farm and the excife were the objects upon which his choice ultimately fixed for future employment and fupport. By the furgeon who attended him during his illnefs, he was recommended with effect to the commiffioners of excife; and Patrick Millar, Efq. of Dalfwinton, deceived, like Burns himfelf and Burns's other friends, into an idea that the poet and exciseman might yet be refpectable and happy as a farmer, generoufly propofed to eftablifh him in a farm, upon conditions of leafe which prudence and induftry might eafily render exceedingly advantageous. Burns eagerly accepted the offers of this benevolent patron. Two of the poet's friends from Airfhire were invited to furvey that farm in Dumfriesfhire which Mr Millar offered. A leafe was granted to the poetical farmer at that annual rent which his own friends declared that the due cultivation of his farm might eafily enable him to pay. What yet remained of the profits of his publication was laid out in the purchafe of farm-ftock; and Mr Millar might, for fome fhort time, pleafe himfelf with the perfuafion that he had approved himfelf the liberal patron of genius; had acquired a good tenant upon his eftate; and had placed a deferving man in the very fituation in which alone he himfelf defired to be placed, in order to be happy to his wifhes.

Burns, with his Jane, whom he now married, took up their refidence upon his farm. The neighbouring farmers and gentlemen, pleafed to obtain for an inmate among them the poet by whofe works they had been delighted, kindly fought his company, and invited him to their houfes. He found an inexpreffible charm in fitting down befide his wife, at his own firefide; in wandering over his own grounds; in once more putting his hand to the fpade and the plough; in forming his enclofures, and managing his cattle. For fome months he felt almoft all that felicity which fancy had taught him to expect in his new fituation. He had been for a time idle; but his mufcles were not yet unbraced for rural toil. He now feemed to find a joy in being the hufband of the miftrefs of his affections, in feeing himfelf the father of her children, fuch as might promife to attach him for ever to that modeft, humble, and domeftic life, in which alone he could hope to be permanently happy. Even his engagements in the fervice of the excife did not, at the very firft, threaten neceffarily to debafe him by affociation with the mean, the grofs, and the profligate, to contaminate the poet, or to ruin the farmer.

But it could not be: it was not poffible for Burns now to affume that fobernefs of fancy and paffions, that fedatenefs of feeling, thofe habits of earneft attention to grofs and vulgar cares, without which fuccefs in his new fituation was not to be expected. A thoufand difficulties were to be encountered and overcome, much money was to be expended, much weary toil was to be exercifed, before his farm could be brought into a ftate of cultivation in which its produce might enrich the occupier. This was not a profpect encouraging to a man who had never loved labour, and who was at this time certainly not at all difpofed to enter into agriculture with the enthufiafm of a projector. The bufinefs of the excife too, as he began to be more and more employed in it, diftracted his mind from the care of his farm, led him into grofs and vulgar fociety, and expofed him to many unavoidable temptations to drunken excefs, fuch as he had no longer fufficient fortitude to refift. Amidft the anxieties, diftractions, and feducements which thus arofe to him, home became infenfibly lefs and lefs pleafing

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fing; even the endearments of his Jane's affection began to lofe their hold on his heart; he became every day lefs and lefs unwilling to forget in riot thofe gathering forrows which he knew not to fubdue.

Mr Millar and fome others of his friends would gladly have exerted an influence over his mind which might have preferved him in this fituation of his affairs, equally from defpondency and from diffipation; but Burns's temper fpurned all controul from his fuperiors in fortune. He refented, as an arrogant encroachment upon his independence, that tenor of conduct by which Mr Millar wifhed to turn him from diffolute conviviality, to that fteady attention to the bufinefs of his farm, without which it was impoffible to thrive in it. His croffes and difappointments drove him every day more and more into diffipation; and this diffipation tended to enhance whatever was difagreeable and perplexing in the ftate of his affairs. He funk, by degrees, into the boon companion of mere excifemen; and almoft every drunken fellow, who was willing to fpend his money lavifhly in the alehoufe, could eafily command the company of Burns. The care of his farm was thus neglected; wafte and loffes wholly confumed his little capital; he refigned his leafe 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 fupport upon his income as an excife-officer.

Yet during this unfortunate period of his life, which paffed between his departure from Edinburgh to fettle in Dumfriesfhire, and his leaving the country, in order to take up his refidence 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 Scottifh fongs, which were publifhed (the words with the mufic) by Mr Johnfon, engraver in Edinburgh, in 4 vols 8vo, Burns, in many inftances, accommodated new verfes to the old tunes with admirable felicity and fkill. He affifted in the temporary inftitution of a fmall fubfcription library, for the ufe of a number of the well-difpofed peafants in his neighbourhood. He readily aided, and by his knowledge of genuine Scottifh phrafeology and manners greatly enlightened, the antiquarian refearches of the late ingenious Captain Grofe. He ftill carried on an epiftolary correfpondence, fometimes gay, fportive, humorous, but always enlivened by bright flafhes of genius, with a number of his old friends, and on a very wide diverfity of topics. At times, as it fhould feem from his writings of this period, he reflected, with inexpreffible heart-bitternefs, 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 foul, and in fome meafure by the very generofity of his nature; on the difgrace and wretchednefs into which he faw himfelf rapidly finking; on the forrow with which his mifconduct oppreffed the heart of his Jane; on the want and deftitute mifery in which it feemed probable that he muft leave her and their infants; nor amidft thefe agonizing reflections did he fail to look, with an indignation half invidious, half contemptuous, on thofe who, with moral habits not more excellent than his, with powers of intellect far inferior, yet bafked in the fun-fhine 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 fupply. His wit became from this time more gloomily farcaftic; and his converfation and writings began to affume fomething of a tone of mifanthropical malignity, by which they had not been before, in any eminent degree, diftinguifhed. But with all thefe failings, he was ftill that exalted mind which had raifed itfelf above the depreffion of its original condition: with all the energy of the lion, pawing to fet free his hinder limbs from the yet encumbering earth, he ftill appeared *not lefs than archangel ruined!*

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His morals were not mended by his removal from the country. In Dumfries his diffipation became ftill more deeply habitual; he was here more expofed than in the country to be folicited to fhare the riot of the diffolute and the idle: foolifh young men flocked eagerly about him, and from time to time preffed him to drink with them, that they might enjoy his wicked wit. The Caledonian Club, too, and the Dumfriesfhire and Galloway Hunt, had occafional meetings in Dumfries after Burns went to refide there, and the poet was of courfe invited to fhare their conviviality, and hefitated not to accept the invitation.

In the intervals between his different fits of intemperance, he fuffered ftill the keeneft anguifh of remorfe, and horribly afflictive forefight. His Jane ftill behaved with a degree of maternal and conjugal tendernefs and prudence, which made him feel more bitterly the evil of his mifconduct, although they could not reclaim him. At laft crippled, emaciated, having the very power of animation wafted by difeafe, quite broken-hearted by the fenfe of his errors, and of the hopelefs miferies in which he faw himfelf and his family depreffed; with his foul ftill tremblingly alive to the fenfe of fhame, and to the love of virtue; yet even in the laft feeblenefs, and amid the laft agonies of expiring life, yielding readily to any temptation that offered the femblance of intemperate enjoyment, he died at Dumfries, in the fummer of 1796, while he was yet three or four years under the age of forty, furnifhing a melancholy proof of the danger of *fuddenly* elevating even the greateft mind above its original level.

After his death, it quickly appeared that his failings had not effaced from the minds of his more refpectable acquaintance either the regard which had once been won by his focial qualities, or the reverence due to his intellectual talents. The circumftances of want in which he left his family were noticed by the gentlemen of Dumfries with earneft commiferation. His funeral was celebrated by the care of his friends with a decent folemnity, and with a numerous attendance of mourners, fufficiently honourable to his memory. Several copies of verfes were inferted in different newfpapers upon the occafion of his death. A contribution, by fubfcription, was propofed, for the purpofe of raifing a fmall fund, for the decent fupport 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 juftly infer him to have been an honeft, proud, warm-hearted man; of high paffions and found underftanding, and a vigorous and excurfive imagination. He was never known to defcend to any act of deliberate meannefs. In Dumfries he retained many refpectable friends even to the laft; and it may be doubted whether any poet of the prefent age has exercifed a greater power over the minds of his readers. Burns has not failed to command

Burram-pooter, Butter.

one remarkable ſort of homage, ſuch as is never paid but to great original genius; a crowd of poetaſters 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 ſalter 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."

Butter.

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 ſlattern 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.

Caffres.

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 vail 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 loft; for a Caffre, if he be not afraid of being hurt or ftung by infects, cares very little whether his cowl be in its place or not. Our author faw one Caffre who, inftead of a cowl, wore a cafe made of wood, and ornamented with fculpture. This was a new and ridiculous fafhion, which he had borrowed from a nation of black people who lived at a great diftance from Caffraria.

In the hot feafon the Caffres go always naked, and retain nothing but their ornaments. In cold weather they wear kroffes made of calves or oxen hides, which reach down to the ground; but whatever the weather be, both fexes go bare-headed, except that they fometimes, though rarely, fix a plume of feathers in their hair.

The Caffre huts are more fpacious and higher than thofe of the Hottentots, and have alfo a more regular form. The frames of them are conftructed of wooden work, well put together, and very folid, being intended to laft for a long time: for the Caffres, applying to agriculture, which the free Hottentots do not, remain fixed to one fpot, unlefs fomething unexpected interrupt their repofe.

A more perceptible induftry, an acquaintance with fome of the moft neceffary arts of life, a little knowledge of agriculture, and a few religious dogmas, feem 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 punifhed, in a future ftate; but they have no notion of creation, which indeed was not admitted by the fages of Greece and Rome. They practife circumcifion, but can give no account of its origin among them, or of the purpofe for which the practice is continued.

Polygamy is ufed among the Caffres; and on the death of a father the male children and their mothers fhare the fucceffion among them. The girls remain with their mothers without property of any kind until they can procure hufbands. One very fingular cuftom of the Caffres is, that they do not, in general, inter their dead, but tranfport them from the kraal to an open ditch, which is common to the whole horde. At this ditch favage animals feed at their leifure on the multitude of carcafes which are heaped together. Funeral honours are due only to kings and the chiefs of each horde, whofe bodies are covered with a heap of ftones collected into the form of a dome.

This nation is governed by a general, chief, or king, whofe power is very limited. He appoints, however, the fubordinate 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 thickeft three inches in diameter, and a plain lance or *affagey*. He defpifes poifoned arrows, which are fo much ufed by fome of the neighbouring nations; and with his two fimple weapons feeks always to meet his enemy face to face in the field. The Hottentot, on the contrary, concealed under a rock or behind a bufh, deals out deftruction, without being expofed to danger. The one is a perfidious tyger, which rufhes treacheroufly on his prey; the other is a generous lion, which, having given warning of his approach, makes his attack boldly, and perifhes if he prevail not againft his antagonift.

Calculus. CALCULUS, in mathematics, denotes a certain way of performing inveftigations and refolutions, which occur on many occafions, particularly in mechanical philofophy. Thus we fay, 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 thefe calculi fome 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 reafoning, without any confideration of motion or velocity, applicable to every purpofe to which the much celebrated doctrine of fluxions of the illuftrious Newton has been, or can be, applied. This method was invented by James Glenie, Efq; "in which (he fays) every expreffion is truly and ftrictly geometrical, is founded on principles frequently made ufe of by the ancient geometers, principles admitted into the very firft elements of geometry, and repeatedly ufed by EUCLID himfelf. As it is a branch of general geometrical proportion, or univerfal comparifon, and is derived from an examination of the antecedents of ratios, having given confequents and a given ftandard of comparifon in the various degrees of augmentation and diminution they undergo by compofition and decompofition, I have called it the antecedental calculus. As it is purely geometrical, and perfectly fcientific, I have, fince it firft occurred to me in 1779, always made ufe of it inftead of the fluxionary and differential calculi, which are merely arithmetical. Its principles are totally unconnected with the ideas of motion and time, which, ftrictly fpeaking, are foreign to pure geometry and abftract fcience, though, in mixed mathematics and natural philofophy, they are equally applicable to every inveftigation, involving the confideration of either with the two numerical methods juft mentioned. And as many fuch inveftigations require compofitions and decompofitions of ratios, extending greatly beyond the triplicate and fubtriplicate, this calculus in all of them furnifhes every expreffion in a ftrictly geometrical form. The ftandards of comparifon in it may be any magnitudes whatever, and are of courfe indefinite and innumerable; and the confequents of the ratios, compounded or decompounded, 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 ftandard of comparifon, but alfo the confequent of every ratio compounded or decompounded."

This method is deduced immediately from Mr Glenie's Treatife on the Doctrine of Univerfal Comparifon or General Proportion: And as the limits of the prefent work will not allow us to enter upon this fubject, we therefore refer our readers to the two above mentioned treatifes, and to the fourth volume of the Tranfactions of the Royal Society of Edinburgh.

We confefs, however, that we do not expect fuch great advantage from the employment of this calculus as the very acute and ingenious author feems to promife from it. The mathematical world is truly indebted to him for the clear and difcriminating view that he has taken

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 recondite speculations of Mr Glenie, in his doctrine of universal comparison.

CALENDAR, in chronology. See *(Encycl.)* KALENDAR; and REVOLUTION, n° 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 $\frac{1}{4}\frac{1}{7}\frac{1}{6}$, 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 Cochin-china, 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° 53′, and 15° 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 semilunar 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 areca, 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 appoach 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

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 preſſingly 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-wha*, or flower of tea, on account of the reſemblance of the one to the other, and becauſe

Campbell. becauſe its petals are ſometimes mixed among the teas to increaſe their fragrance. Sir George Staunton, who calls it *Camellia Seſanqua*, 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 Banchary 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 became 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 relevation 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 affections 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. 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 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 agreable 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

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.

CAMPHOR, 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.

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 Russel-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 expressed

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, where 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, perhaps,

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. *d d d*, where the wall rises only to the height of the water in the upper reach, and *e e*, two pillars, raised high enough to support the pivots of a wheel or pulley *g*, placed in the position there marked.

"The second division *h* 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 *h* 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.

"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.

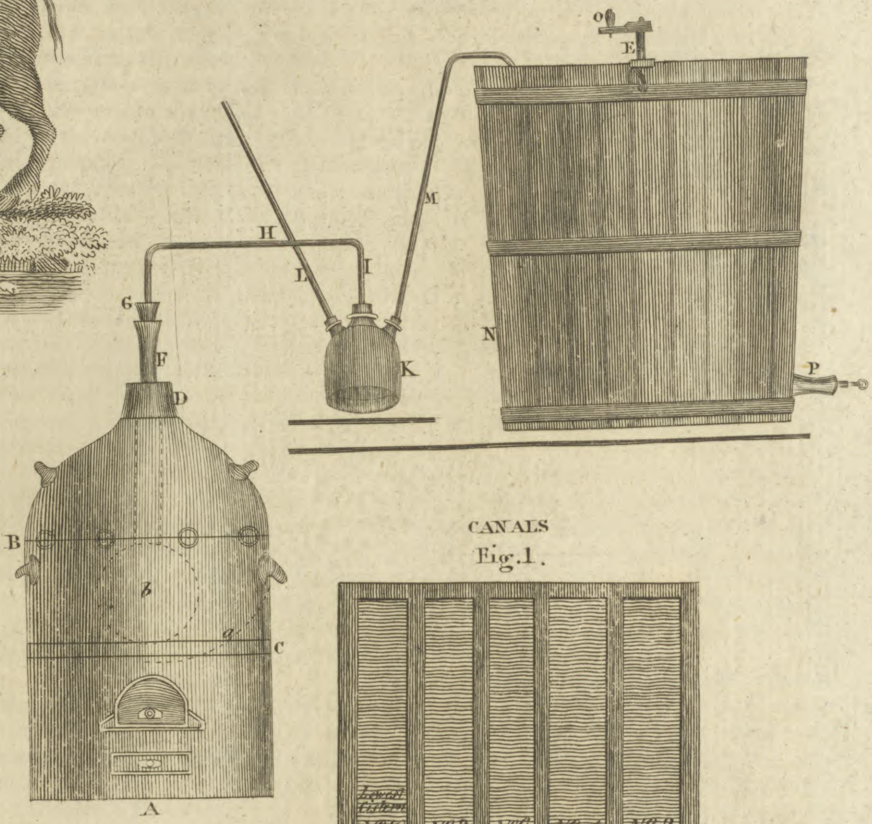
"Things being thus arranged, you are to suppose the coffer *h* to be suspended, by means of a chain passed over the pulley, and balanced by a weight that is sufficient to counterpoise it, suspended at the opposite end of the chain. Suppose, then, that the counterpoise be made somewhat lighter than the coffer with its contents, and that the line *m n* (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 lists 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 *p p* (fig. 2.) In fig. 3. *h* 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 *h* 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 *h* 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 *h* (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 *r s*, fig. 6. (which juncture is covered with lists of cloth, as before explained, at *m n*, and is of course become water-tight), when, by lifting the sluice *t*, 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

BLEACHING



CANALS

Fig. 1.

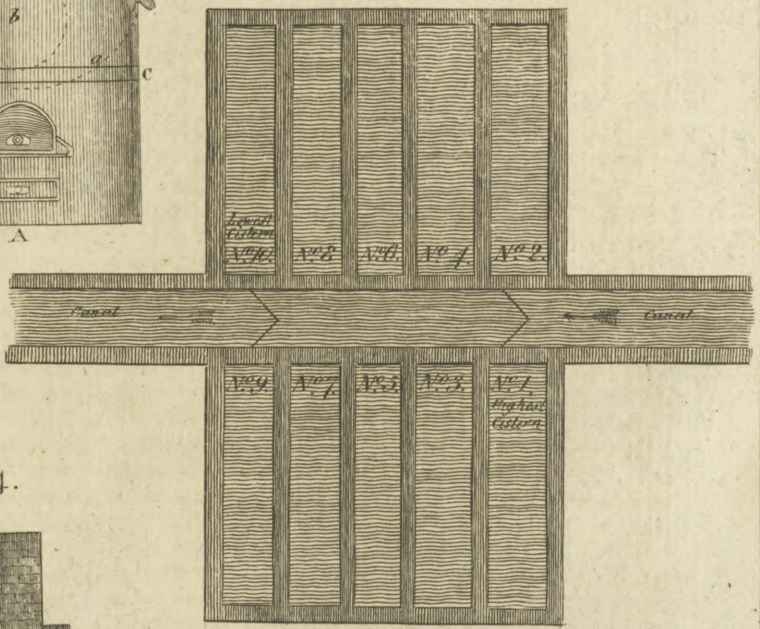


Fig. 2.

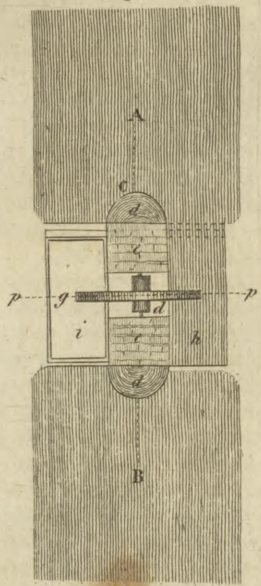


Fig. 3.

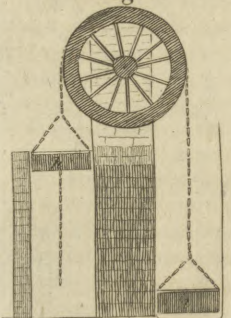


Fig. 4.

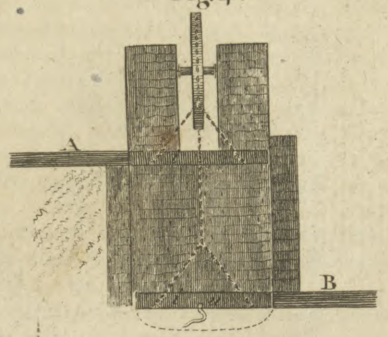


Fig. 5.

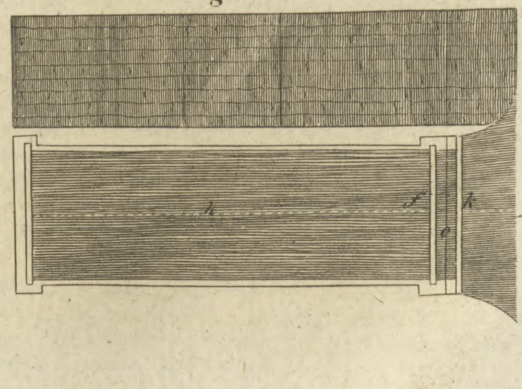
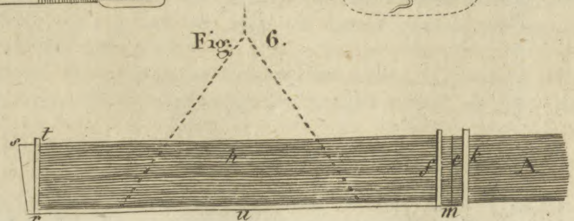


Fig. 6.



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 diminiſhed 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."

being made so immoveably 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 sugar-cane, 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 Ymst 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 bulfinches (*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 *Scaghiola*. 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 Rocolla* 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 volatilized matter, which does not become ignited till it has ascended towards the point. When the wick is either

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 unfused 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 *pela* 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.

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 ſuperſaturated 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

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 Encyclopædia. 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 soldering 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 incon-

Caoutchouc.

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 expence 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 expence 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.

CAP and BUTTON, are two ſmall iſlands, or rather rocks, lying in longitude 105° 48′ 30″ 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 miſhapen, 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.

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 tutelar 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 || Carp.

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*.

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 present 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 chissel 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° 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 only 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.

6 Illustrated by experiment.

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 *d* A 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. 7 Considered 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

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 uninſtructed 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 repreſented 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.

8
Rule for diſtinguiſhing the caſes of compreſſion and extenſion.

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.

In

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.

10 Strains propagated to the points of ſupport.

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 ſubject 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.

11 Action of a ſtraining beam.

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.

12 The form of the abutting joint of no great importance.

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 perdendicular 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*; of of which A f muſt be reſiſted by the beam HD, and A e by the beam AD. The preſſure A f 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 A f will be reſiſted by HD with the force p A; but there is required another force i A, 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 A e 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 A e, as well as by A f. To find what this preſſure on HD is, draw $e\,g$ perpendicular to HD, and $e\,o$ parallel to it, cutting EG in r. The forces g A and o A will reſiſt, and balance A e.

Thus we ſee, that the two forces A e and A f, which are equivalent to AE, are equivalent alſo to A p, A i, A o, and A g. But becauſe A f and e E are equal and parallel, and E r and $f\,i$ are alſo parallel, as alſo $e\,r$ and $f\,p$, it is evident, that $i\,f$ is equal to r E, or to o F, and i A is equal to $r\,e$, or to G g. Therefore the four forces A g, A o, A p, A i, 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.

13 Origin of the ſtrain on a tie-beam.

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 A b of the vertical or plumb line, intercepted between the ridge and the beam. Then drawing $b\,f$ and $b\,g$ parallel to AD and AC, A g and A f will repreſent the preſſures on AC and AD. Produce AC till CH be equal to A f. 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 A b. If we draw HK parallel to DC, and HI parallel to CK (that is, to A b), 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 = A g, and completing the parallelogram DMNO, the point D would be ſupported by the forces OD and MD. If we draw $g\,o$ and $f\,k$ parallel to DC, it is plain that they are equal to NO and CK, while A o and A k are equal to DO and CK, and A b is equal to the ſum of DO and CK (becauſe it is equal to A o + A k). 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 A b, produces the ſtrains A f and A g, 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.

14 External action of a frame.

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:

$$\text{DO} : \text{DM} = \text{A}b : b\text{D}$$
$$\text{CI, or DM} : \text{CK} = \text{C}b : \text{A}b$$
$$\text{Therefore DO} : \text{CK} = \text{C}b : b\text{D}.$$

Or, *the preſſures on the points* C *and* D, *in the direction of the ſtraining force* A b, *are reciprocally proportional to the portions of* DC *intercepted by* A b.

Alſo, ſince A b is = DO + CK, we have

$\text{A}b : \text{CK} = \text{C}b + b\text{D}$ (or CD) : bD, and

$\text{A}b : \text{DO} = \text{CD} : b\text{C}$.

In general, any two of the three parallel forces A b, 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 A b, and with an intenſity which may be meaſured by A b, may be ſet in equilibrio, with another acting at C, in the direction CL, oppoſite to CK or A b, 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 A b to be balanced by 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 *k l*, *n o* 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 lC 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 Ad, Bf perpendicular to CQ and CP; and draw Cg, Ci perpendicular to AE, BF.

The triangles CPR and BPf are similar, having a common angle P, and a right angle at R and f.

In like manner the triangles CQS and AQd 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:

$$Co : CP = On : PB, = CG : PB$$
$$CP : CR = \quad PB : fB$$
$$CR : CS = \quad CH : CG$$
$$CS : CQ = \quad Ad : AQ$$
$$CQ : Cl = AQ : Kl, = AQ : CH.$$

Therefore, by equality,

$$Co : Cl = \quad Ad : fB$$
$$\text{or } BO : AL = \quad Cg : Ci.$$

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 problems 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 (n° 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 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, n° 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 A *f* and A *g*. Complete the parallelogram, and A *a* 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 H *b* and H *c* must be equal to A *f* and A *g*, and the weight *b* H which breaks them must be equal to A *a*.

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 $= a\text{ A} + b$, or twice A *a*.

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.

19 The best manner of framing purlins.

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.

20 Ties are in general better than struts.

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 $4\frac{1}{2}$ 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

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° 19. and *Strength of Materials*, n° 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 ſound oak, m is very nearly $= \frac{1}{9}$ (ſee *Strength of Materials*, n° 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 $w = \frac{f b d^2}{9 CB}$, 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 $(= w) = f \times \frac{b d^2 \times AB}{9 AC \times CB}$.

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 $w = \frac{16000 \times 4 \times 16 \times 84}{9 \times 42 \times 42}$, or $w = \frac{86016000}{15876}$, $= 5418$ 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.

22 Of joints.

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.

25
Joggling preferable to scarfing.

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 joggling 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.

26 We muſt not wedge too hard. 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 deſultory 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
27 Building of maſts. 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
28 Method uſed in the French Navy. 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 *e f*, 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 29 Another method.
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 *a b*, the beam is weaker than fig. 20. bent in the direction *e f*. 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 butments 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 30 Its imperfection.
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. *a b* and *c d* 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 31 Britiſh method;
different from any of theſe methods. The pieces are tabled as in fig 22. but the tables are not thin parallelopipeds, but thin priſms. The two outward joints or viſible ſeams are ſtraight lines, and the table n° 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,

fections, at leaft in the particular cafe of a round maft: it will draw together by hooping incomparably better than any of the others. If the cavity be made fomewhat too fhallow for the prominence of the tables, and if this be done uniformly along the whole length, it will make a fomewhat open feam; and this opening can be regulated with the utmoft exactnefs from end to end by the plane. The heart of thofe vaft trunks is very fenfibly fofter than the exterior circles: Therefore, when the whole is hooped, and the hoops hard driven, and at confiderable intervals between each fpell —we are confident that all may be compreffed till the feam difappears; and then the whole makes one piece, *much* ftronger than if it were an original log of that fize; becaufe the middle has become, by compreffion, as folid as the cruft, which was naturally firmer, and refifted farther compreffion. We verified this beyond a doubt, by hooping a built ftick of a timber which has this inequality of firmnefs in a remarkable degree, and it was nearly twice as ftrong as another of the fame fize.

Our maftmakers are not without their fancies and whims; and the manner in which our mafts and yards are generally built up, is not near fo fimple as fig. 22.: but it confifts of the fame effential parts, acting in the very fame manner, and derives all its efficacy from the principles which are here employed.

32 Attended with peculiar advantages.

This conftruction is particularly fuited to the fituation and office of a fhip's maft. It has no bolts; or, at leaft, none of any magnitude, or that make very important parts of its conftruction. The moft violent ftrains perhaps that it is expofed to, is that of twifting, when the lower yards are clofe braced up by the force of many men acting by a long lever. This form refifts a twift with peculiar energy: it is therefore an excellent method for building up a great fhaft for a mill. The way in which they are ufually built up is by reducing a central log to a polygonal prifm, and then filling it up to the intended fize by *planting* pieces of timber along its fides, either fpiking them down, or cocking them into it by a feather, or joggling them by flips of hard wood funk into the central log and into the flips. *N. B.* Joggles of elm are fometimes ufed in the middle of the large tables of mafts; and when funk into the firm wood near the furface, they muft contribute much to the ftrength. But it is very neceffary to employ wood not much harder than the pine; otherwife it will foon enlarge its bed, and become loofe; for the timber of thefe large trunks is very foft.

The moft general reafon for piecing a beam is to increafe its length. This is frequently neceffary, in order to procure tie-beams for very wide roofs. Two pieces muft be fcarfed together.—Numberlefs are the modes of doing this; and almoft every mafter carpenter has his favourite noftrum. Some of them are very ingenious: But here, as in other cafes, the moft fimple are commonly the ftrongeft. We do not imagine that any, the moft ingenious, is equally ftrong with a tie confifting of two pieces of the fame fcantling laid over each other for a certain length, and firmly bolted together. We acknowledge that this will appear an artlefs and clumfy tie-beam; but we only fay that it will be ftronger than any that is more artificially made up of the fame thicknefs of timber. This, we imagine, will appear fufficiently certain.

33 Various methods of fcarfing.

The fimpleft and moft obvious fcarfing (after the one now mentioned) is that reprefented in fig. 24. n° 1. and 2. If confidered merely as two pieces of wood joined, it is plain that, as a tie, it has but half the ftrength of an entire piece, fuppofing that the bolts (which are the only connections) are faft in their holes. N° 2. requires a bolt in the middle of the fcarf to give it that ftrength; and, in every other part, is weaker on one fide or the other.

But the bolts are very apt to bend by the violent ftrain, and require to be ftrengthened by uniting their ends by iron plates; in which cafe it is no longer a wooden tie. The form of n° 1. is better adapted to the office of a pillar than n° 2.; efpecially if its ends be formed in the manner fhewn in the elevation n° 3. By the fally given to the ends, the fcarf refifts an effort to bend it in that direction. Befides, the form of n° 2. is unfuitable for a poft; becaufe the pieces, by fliding on each other by the preffure, are apt to fplinter off the tongue which confines their extremity.

Fig. 25. and 26. exhibit the moft approved form of a fcarf, whether for a tie or for a poft. The key reprefented in the middle is not effentially neceffary; the two pieces might fimply meet fquare there. This form, without a key, needs no bolts (although they ftrengthen it greatly); but, if worked very true and clofe, and with fquare abutments, will hold together, and will refift bending in any direction. But the key is an ingenious and a very great improvement, and will force the parts together with perfect tightnefs. The fame precaution muft be obferved that we mentioned on another occafion, not to produce a conftant internal ftrain on the parts by overdriving the key. The form of fig. 25. is by far the beft; becaufe the triangle of 26. is much eafier fplintered off by the ftrain, or by the key, than the fquare wood of 25. It is far preferable for a poft, for the reafon given when fpeaking of fig. 24. n° 1. and n° 2. Both may be formed with a fally at the ends equal to the breadth of the key. In this fhape, fig. 25. is vaftly well fuited for joining the parts of the long corner pofts of fpires and other wooden towers. Fig. 25. n° 2. differs from n° 1. only by having three keys. The principle and the longitudinal ftrength are the fame. The long fcarf of n° 2. tightened by the three keys, enables it to refift a bending much better.

None of thefe fcarfed tie-beams can have more than one-third of the ftrength of an entire piece, unlefs with the affiftance of iron plates; for if the key be made thinner than one-third, it has lefs 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 fimple form of fig. 24. n° 1. is ftronger than thofe more ingenious fcarfings. It may be ftrengthened againft lateral bending by a little tongue, or by a fally; but it cannot have both.

The ftrongeft of all methods of piecing a tie-beam would be to fet the parts end to end, and grafp them between other pieces on each fide, as in fig. 27. This is what the fhip-carpenter calls *fifhing* a beam; and is a frequent practice for occafional repairs. Mr Perronet ufed it for the tie-beams or ftretchers, by which he connected the oppofite feet of a centre, which was yielding to its load, and had pufhed afide one of the piers above four inches. Six of thefe not only withftood a ftrain of 1800 tons, but, by wedging behind them, he brought

34 Fifhing a beam.

brought the feet of the truſs 2$\frac{1}{2}$ inches nearer. The ſtretchers were 14 inches by 11 of ſound 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 *(Trait 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
35 joints of a piece of carpentry.

Square joints.

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
36 not be, leſt they ſhould be crippled in driving. They
Foxtail wedging.
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 *a b* gives a very firm ſupport to the additional bearing *e d*, 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 atten- 37
Oblique mortiſe and tenon.
tion 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 *a b* cut perpendicular to the ſurface of the tie-beam, and the reſt *b c* 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

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 nostrum, and we shall only mention a few that are most generally approved of.

38 Most approved 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 *a b c d e f g* 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 *b d* and *d f* are so short that the little wooden triangles *b c d*, *d e f*, will be easily pushed off their bases *b d*, *d f*.

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 *a c* is nearly perpendicular to *b d*. The lower angle of the tenon is cut off horizontally as at *e d*. 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 *a b*, *a c*, *e d*, 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 *e c i*, having its face *i c* 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 *c i* would have prevented the sliding upwards along *e c*. At any rate, the joint *a b* being flush with the beam, prevents any sensible abutment on the shoulder *a c*.

Fig. 33. n° 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° 3. is also much practised by the first carpenters.

Fig. 35. is proposed by Mr Nicholson (page 65.) as preferable to fig. 33. n° 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° 2.

39 Circumstances to be attended to.

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

the head of the main posts of Drury Line theatre, fig. D.

40 Butting joints.

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° 2. where the straining beam *a b* 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.

41 Directions for placing iron straps.

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° 36. and 41. of the article Roof, *Encycl.* In n° 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. 42 Examples of different pieces of carpentry.

Fig. 38. is the roof of the chapel of the Royal Hospital at Greenwich, constructed by Mr S. Wyatt. 43 Roof of Greenwich chapel.

	Inches Scantling.
AA, Is the tie-beam, 57 feet long, spanning 51 feet clear - - - - -	14 by 12
CC, Qneen-posts - - - - -	9×12
D, Braces - - - - - -	9×7
E, Truss beam - - - - -	10×7
F, Straining piece - - - - -	6×7
G, Principal rafters - - - -	10×7
H, A cambered beam for the platform -	9.7
B, An iron string, supporting the tie-beam	2×2

The trusses are 7 feet apart, and the whole is covered with lead, the boarding being supported by horizontal ledgers *h*, *h*, 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. 44 St Paul's, Covent Garden.

AA, Tie-beam spanning 50 feet 2 inches	16.12
B, Queen-post - - - - -	9×8
C, Truss beam - - - . - -	10×8
D, King-post (14 at the joggle) - -	9×8
E, Brace - - - - - -	8×7½
FF, Principal brace (at bottom) - -	10×8½
HH, Principal rafter (at bottom) -	10×8½
gg, Studs supporting the rafter - -	8×8

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 Price,

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 ſill - - - -	5½×9

This roof is a fine ſpecimen of Britiſh carpentry, and is one of the boldeſt and lighteſt roofs in Europe. The ſtraining ſill Q gives a firm abutment to the principal braces, and the ſpace between the poſts is 19½ feet wide, affording roomy workſhips 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.

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. 47 Remarks.

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.

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 nº 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 ſill. 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. 48 Project by Mr Nicholſon.

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

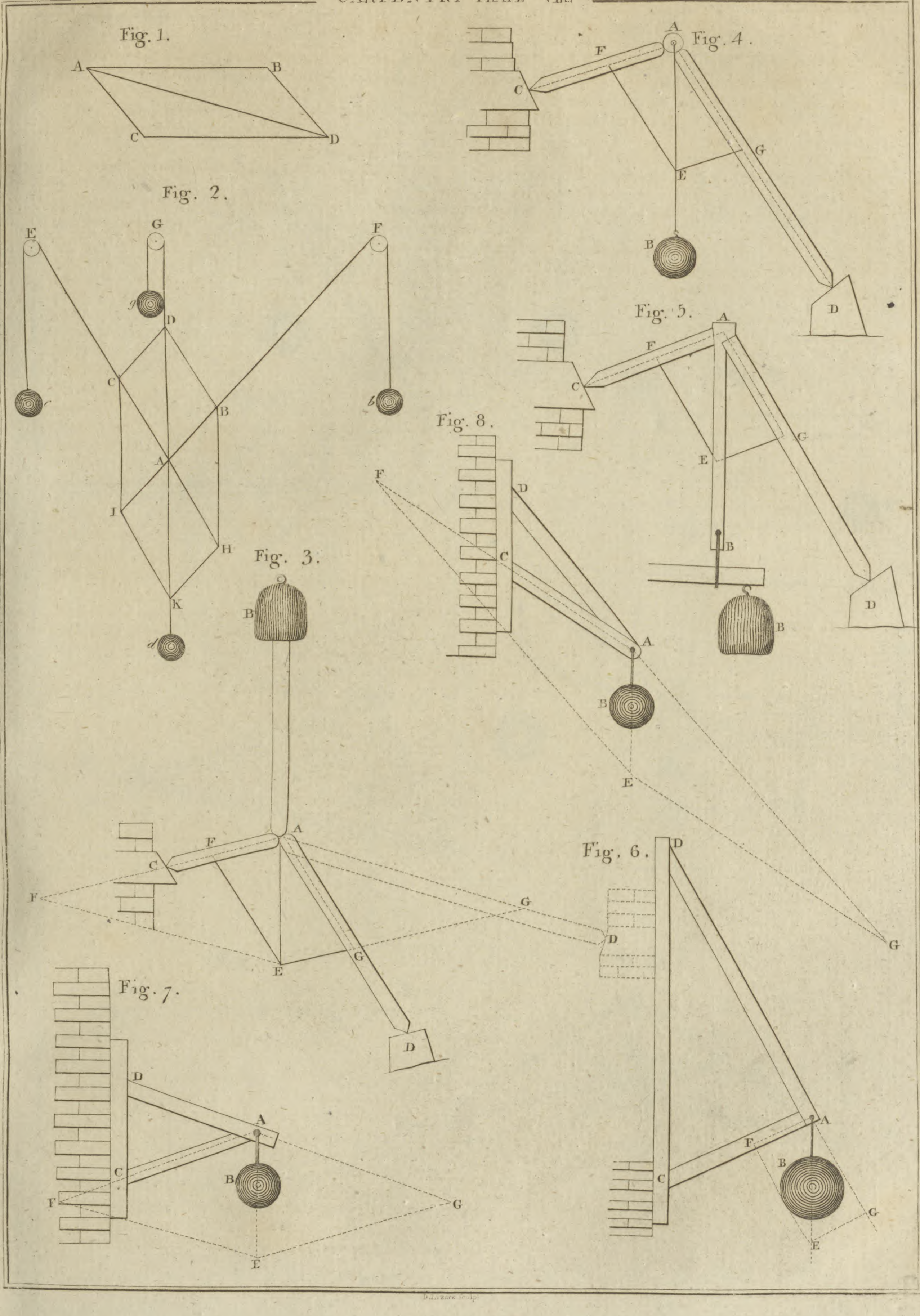


Fig. 1.
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Fig. 2.
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Fig. 3.
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Fig. 6.
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Fig. 8.
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Fig. 9.

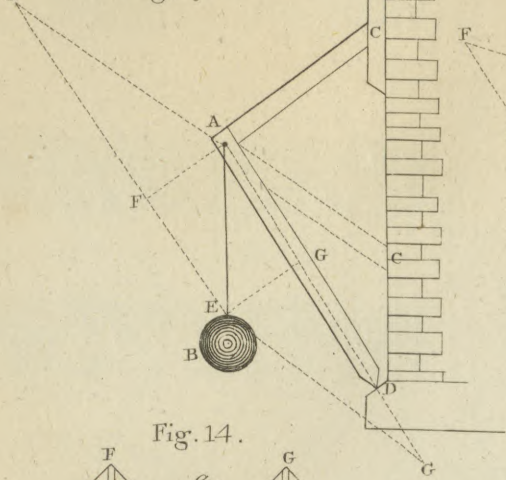


Fig. 10.

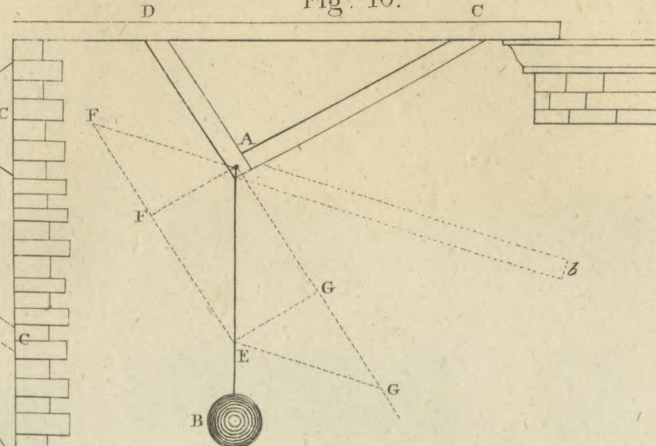


Fig. 15.

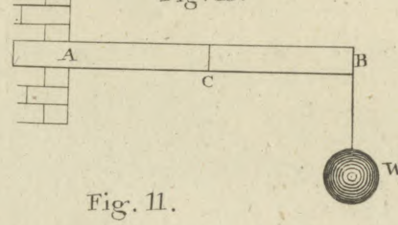


Fig. 14.

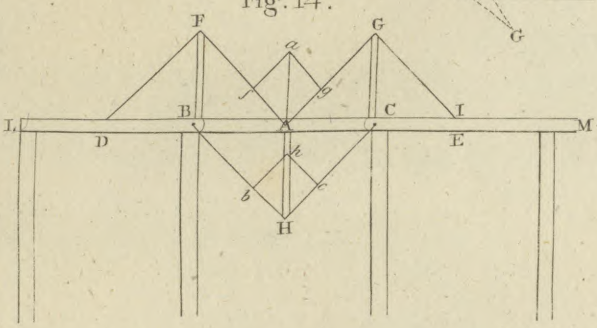


Fig. 11.

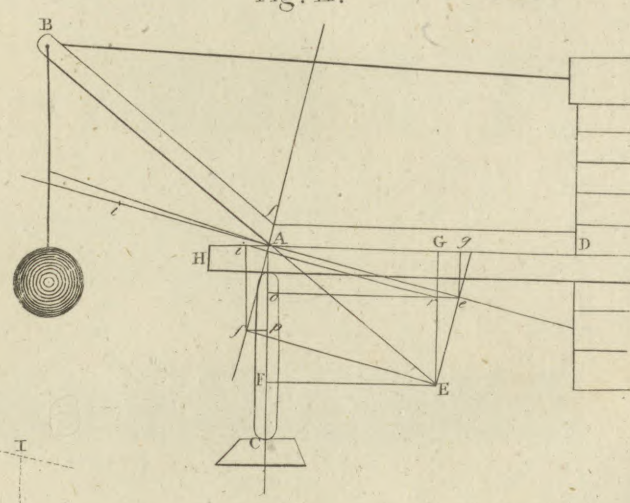


Fig. 12.

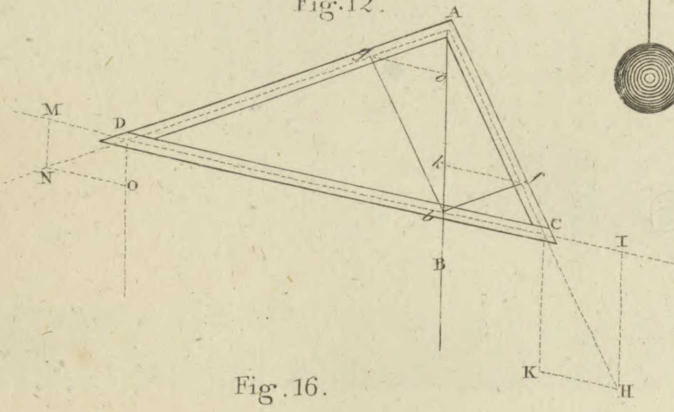


Fig. 16.

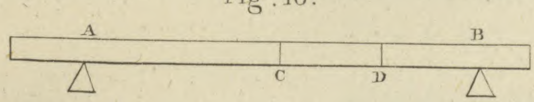
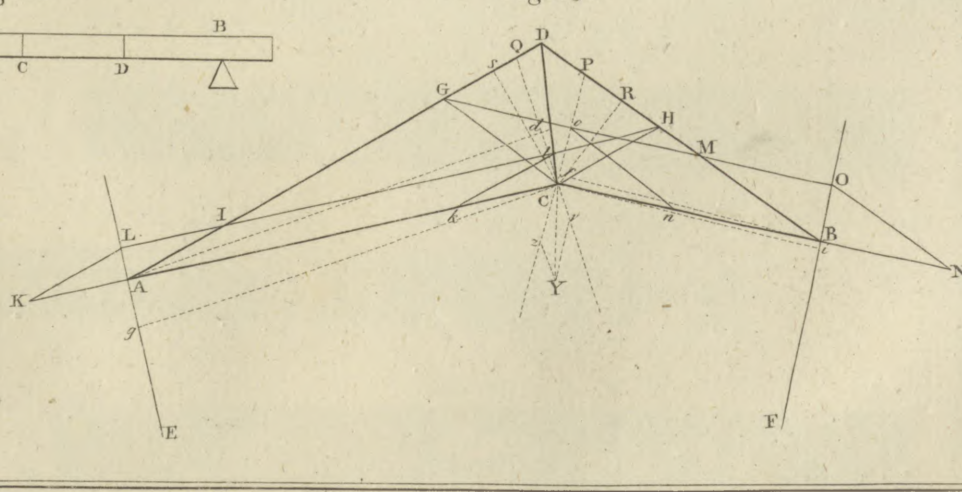


Fig. 13.



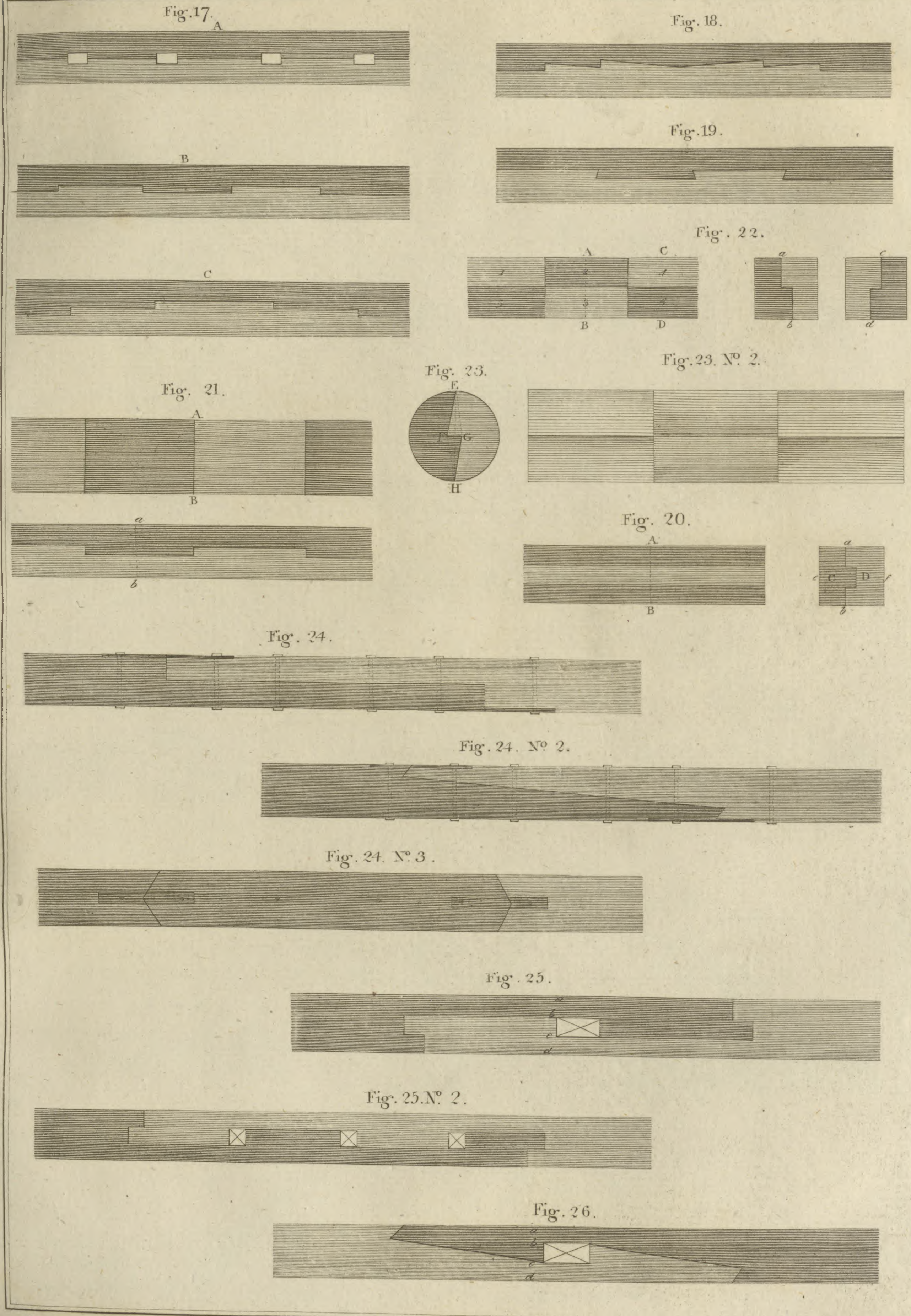


Fig. 17.
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Fig. 18.
Fig. 19.
Fig. 22.
Fig. 21.
Fig. 23.
Fig. 23. N°. 2.
Fig. 20.
Fig. 24.
Fig. 24. N°. 2.
Fig. 24. N°. 3.
Fig. 25.
Fig. 25. N°. 2.
Fig. 26.

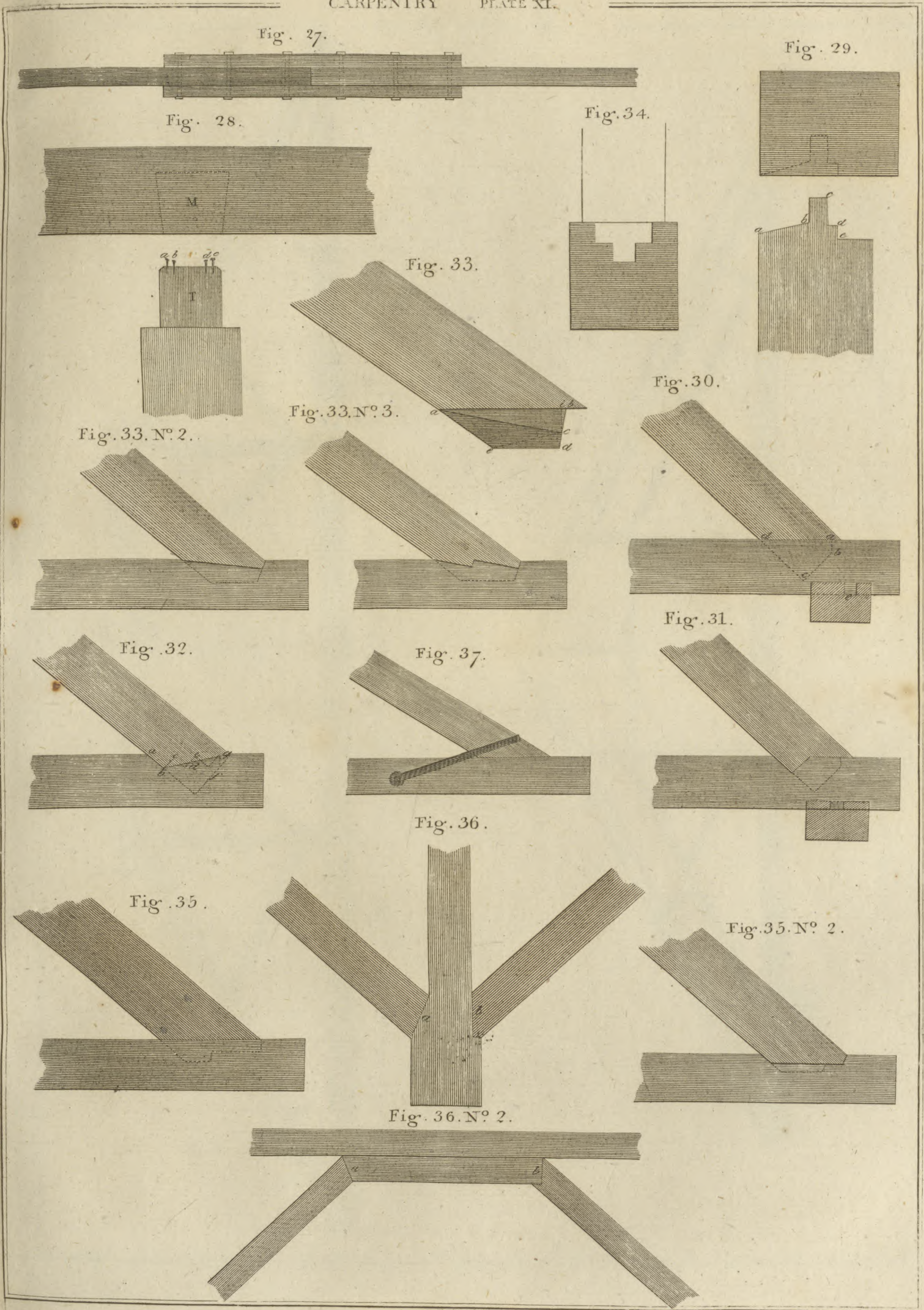
Fig. 27.
Fig. 28.
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Fig. 33.
Fig. 33. N.° 3.
Fig. 33. N.° 2.
Fig. 30.
Fig. 31.
Fig. 32.
Fig. 37.
Fig. 36.
Fig. 35.
Fig. 35. N.° 2.
Fig. 36. N.° 2.

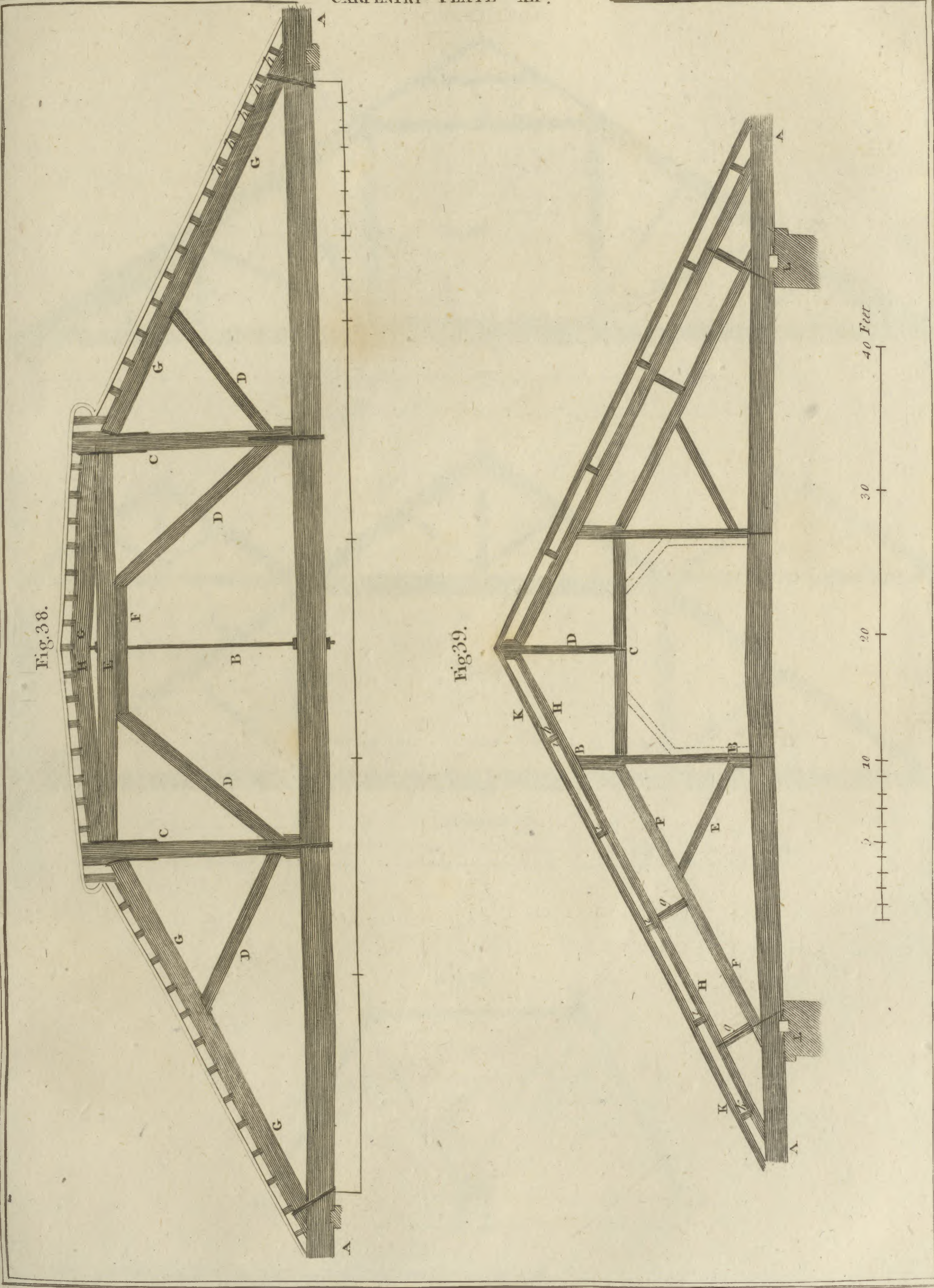


Fig.38.
Fig.39.
40 Feet
30
20
10

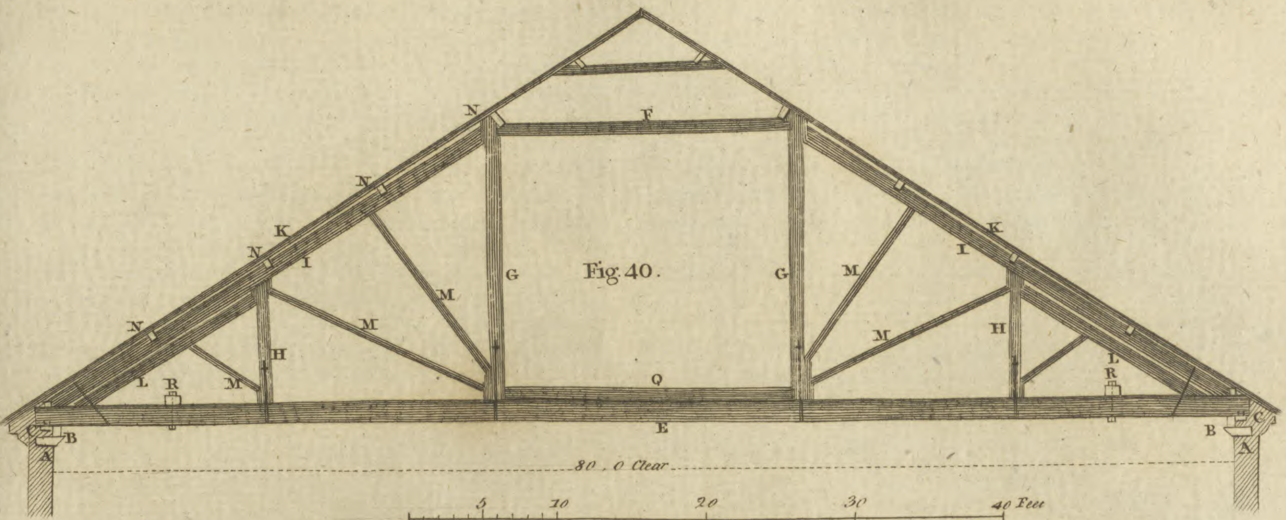


Fig. 40.

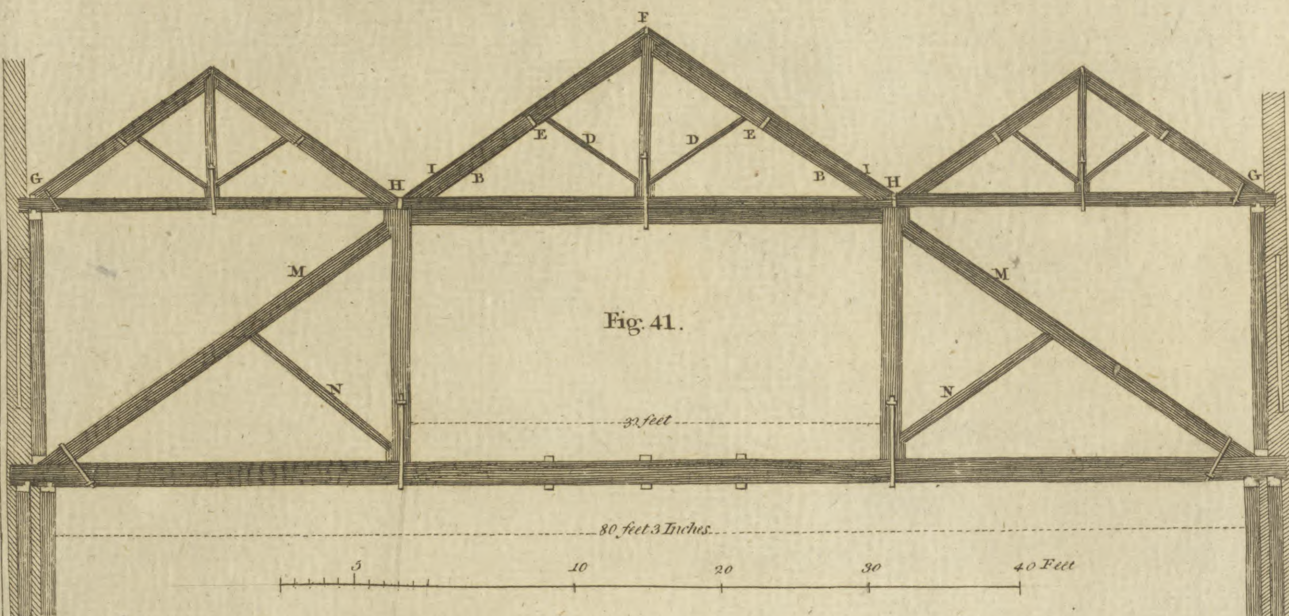
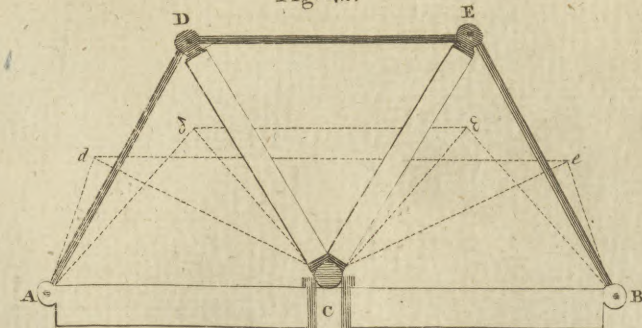


Fig. 41.

Fig. 42.



49 Wooden bridges. 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 bridles, 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.

50 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° 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 A *d e* B, or A δ ε 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.

Caſcabel || Caſſini. 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.

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 *Encyclopædia*.

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 Caſſini.

Caſſini. 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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Cassini || Catalogues of Books.

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 1783 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 smallpox 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.

Catalogues of Books.

According to the Professor, George Willer, whom some improperly call Viller, and others Walter, a bookseller 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 booksellers, 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 booksellers of Leipsic 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 Leipsic, 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 Leipsic. Printed at Leipsic 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.*

Reimmann says, that after Willer's death the catalogue was published by the Leipsic bookseller 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 bookselling was drawn from Franckfort to Leipsic, 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.

naſteries, 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 ſæculi ejuſque virorum litteratorum monumentis tum florentiſſimi, tum fertiliſſimi, ab anno* 1500 *ad* 1602 *nundinarum autumnalium incluſive, elenchus conſummatiſſimus—deſumtus 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 incorrectly; 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 *Encyclopædia.* 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 *Aſtronomiæ 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 *Cœlum 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'Arquier, 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. Tranſ. for 1782 and 1783; Meſſier's nebulæ and cluſters of ſtars, publiſhed in the *Connoiſſance des Temps* for 1784; and Herſchel's catalogue of the ſame kind, given in the Phil. Tranſ. 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, *Tabulæ 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."

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 β δ ϵ 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

Catalogues of the Stars.

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 *ſuns*, 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 Urſæ 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 Lyræ 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 κ 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 alledged that the periods in the change of luſtre of ſome ſtars, ſuch as Algol, β Lyræ, δ Cephei, and η Antinoi, are ſhort, being only 3, 5, 6, and 7 days reſpectively; while thoſe of *o* 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 *o* 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, Catharine.

na that may then offer themſelves to our extended views." 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 fortreſs 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 unprincely 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 fhe could not find in the fociety of her hufband. She was fond of pleafure; but it was that comparatively refined pleafure which fhe had enjoyed at the court of Berlin. She loved balls, mufic, and elegant converfation, and could take no fhare in the drunken revels of Peter. Among the young men with whom he was furrounded, his chamberlain Soltikoff was particularly remarked for the elegance of his tafte and the graces of his perfon; and though yet fcarcely more than a boy in years, he was faid to have obtained the favours of feveral ladies of the court. Succefs had made him confident and ambitious; and his ambition prompted him to afpire at making a conqueft even of the Grand Duchefs. By ftudying her tafte, and contriving to amufe her, he was at laft fuccefsful; and obtained from her Imperial Highnefs every favour which he could wifh: but he enjoyed not his fortune with moderation, and his enemies contrived to get him placed in an honourable office at a diftance from the court. He was commiffioned 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 juft been delivered *. The prefumptuous Soltikoff, proud of the employment, fet off with hafte to Sweden, and left it with equal fpeed. But fcarcely had he quitted Stockholm, on the wings of love and ambition, when he was ftopped on the road by a courier, who put into his hands an order for him to go immediately to Hamburg, and there to refide in the quality of minifter plenipotentiary from the court of Ruffia.

* Oct. 1. 1754.

Catharine for fome time preferved her attachment to the exiled chamberlain; but all at once the prefence of a ftranger, whom fortune had brought to the court of Ruffia, made her forget the lover whom fhe no longer faw. This perfon was Staniflaus Poniatowfky, the late king of Poland, who firft made his appearance at St Peterfburg in the train of the Britifh ambaffador, and very quickly gained the affections of the Grand Duchefs. In carrying on this intrigue, the lovers were not fo cautious as to deceive the eyes of the envious courtiers, who reported to the emprefs not only all that they faw, but whatever they fufpected. Elizabeth was incenfed, and commanded Poniatowfky to quit without delay the dominions of Ruffia. The accomplifhed Pole obeyed; but foon returned clothed with a character which made him in fome degree independent of the emprefs.

The Count de Bruhl, then prime minifter to the king of Poland, faw of what importance it was to his mafter to have a powerful intereft at the court of Ruffia. He was likewife no ftranger to the paffion which the Grand Duchefs entertained for Poniatowfky; and having got that nobleman decorated with the order of the White Eagle, he fent him back to St Peterfburgh in the quality of minifter plenipotentiary from the republic and king of Poland. Nor was this all that Bruhl did for the two lovers. Being informed by the chancellor Beftucheff, that the Grand Duke and Grand Duchefs were languifhing in a penury unworthy of their rank, he remitted to Poniatowfky 6000 ducats, to be employed, in fuch a manner as he might judge beft, for fecuring the favour of the prince and his confort. The ambaffador profited by thefe counfels and benefactions. He was already fure of the Grand Duchefs's heart, and he very quickly gained the favour of her hufband. He talked Englifh and German with him; drank, fmoked, abufed the French, and extolled the king of Pruffia with unlimited praife.

The Grand Duchefs was fo blinded by her paffion, that fhe was never without Poniatowfky in her company. She devoted to him the whole of her time; and fhe made this intimacy fo little a fecret, that public report was loud to her prejudice. In the mean time fhe was delivered of the Princefs Anne†, who lived only fifteen months. The Grand Duke was the only perfon about court who feemed to know nothing of what was paffing. His whole time was occupied in copying, with fervile affectation, the air, the manners, the tone of the king of Pruffia; and in dreffing a little army at Oranianbaum in the Pruffian uniform. His eyes, however, were at laft opened. Some of the courtiers, from hatred to the chancellor, who countenanced the intrigue between the Grand Duchefs and the Polifh ambaffador, roufed his jealoufy in order to deftroy their enemy. They fucceeded. He forbade his wife to be feen with Poniatowfky, and prevailed with the emprefs to deprive the chancellor of his office, and to banifh him to an eftate which he had 120 verfts beyond Mofcow.

† February 1758.

Catharine had now to fupport at once the averfion of her hufband, the indignation of the emprefs, the infulting difdain of a court, which a few days before was lavifh of its affiduities and fmiles; and what afflicted her moft of all, the dread of lofing for ever her favourite Poniatowfky. Her courage, however, did not forfake her. Poniatowfky was indeed recalled, and left Ruffia, after fuffering fome deferved 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 fifter to the Princefs Dafhkoff, who acted fo confpicuous a part in the revolution which fet the crown on the head of Catharine. She was beautiful, but vain; and poffeffed not either the wit or the underftanding of her fifter.

In the mean time the health of the emprefs vifibly declining, Catharine was very defirous of being reconciled to her: but the irritated fovereign would liften to no accommodation, except on terms too humiliating for the haughty fpirit of the Grand Duchefs. Catharine, therefore, abfented herfelf from court, and afked permiffion to retire into Germany. This, as fhe had forefeen, was refufed. Elizabeth was too fond of the young Paul Petrovitch to permit the departure of his mother, and thereby expofe him to the danger of being at fome future period declared illegitimate. She took the Grand Duchefs again into favour; and it is thought, that had fhe lived a little longer than fhe did, fhe would have excluded Peter from the throne, and declared Paul her immediate fucceffor.

Whilft the emprefs was meditating the aggrandifement of the young prince and his mother, the Grand Duke had conceived a plan for degrading them both. He had refolved, at the moment his aunt fhould clofe her eyes, to affemble his troops, to get himfelf proclaimed emperor, to repudiate the Grand Duchefs, to declare the young Paul Petrovitch illegitimate, and publicly to marry his miftrefs Elizabeth Romanovna Vorontzoff. We have fhewn elfewhere (fee Russia, n° 72. *Encycl.*) how this plan, when almoft ready to be carried into execution, was betrayed to Catharine, who, ever fince her caballing with the Chancellor Beftucheff, had refolved, 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 Duchess 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 accosted 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 Petersburgh, 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 wise 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 hurried him indeed into the most extravagant follies. Not 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, dismissed 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 recal 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 Petersburgh, 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, however, 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 Kosacks, 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 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 Petersburgh; 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 Petersburgh: 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 Petersburgh: 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 Petersburgh, 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 Panin 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.

* July 10.

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 Nesky, 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 recognised 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 Petersburgh.

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 imprudence 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. at

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 Peterſburgh, 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 embrued 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 Peterſburgh, 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; when Orloff recovered his former aſcendency, 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 solicitudes 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 proficients 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 Petersburgh, 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. Catharine.

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 Petersburgh. 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 unsuspicious lady was induced to accept of him as a husband. The ruffian 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 Petersburgh; where, upon her arrival, the princess was shut up in the fortress; 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 Pugetſhoff, 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 Pugetſhoff; 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, Catharine. 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 Peterſburgh 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 preceptrix; 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 recommend

(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 ween 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 behind her the character of one of the greatest sovereigns that ever swayed a sceptre.

Cauda, Cause.

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 *Lucida 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, *Alrukabah*; 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; and

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° 109, &c.—PHILOSOPHY and PHYSICS, *passim*—and (*Suppl.*) ACTION and ASTRONOMY.

1 Definition. CENTER, or CENTRE, a word borrowed from the French name *ceintre* or *cintre*, 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 keystone 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 intermediate 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.

Center. 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 acccordingly. 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 corniche whereon to rest it.

6 The earliest theory, on scientific principles,

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 aukwardly, 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 Illustrated. Plate XIV.

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 Propriety of this arrangement.

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 the

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 $\frac{4}{9}$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.

9 By a centre of M. Pitot's.

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 ſrame 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. 10

The ſtrength of this frame.

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 $\frac{1}{17}$th larger than ours, and the ſuperficial dimenſions (by which the ſection and the abſolute ſtrength is meaſured) is almoſt $\frac{1}{8}$th larger than ours. The cubic foot, by which the ſtones are meaſured, exceeds ours nearly $\frac{1}{5}$th. The pound is deficient about $\frac{1}{13}$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 $\frac{11}{14}$ths of this weight is carried by the frame. We believe, however, that this is nearer the truth than Mr Couplet's aſſumption of $\frac{4}{9}$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. 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 $\frac{11}{14}$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.

11 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 Msrv. 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 Msrv (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. 12 A centre on the same principles for an elliptical arch.

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 ML.

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 = $\frac{1}{4}$CY. Describe the semicircle ZÆY, and make ZS = ZÆ. S is the centre of the side arches, each of 60 degrees. The centre T of the 13 How to construct 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° 2.) be the axes of an ellipse, C the centre, and F, *f* the two foci. Make C*b* = CD, and describe a circle AD*be* 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 AD*be*. 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 D*d* 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 AD*be* 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 *aghb* 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 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 LL, 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 Perrault; as may be seen in the collection of machines and inventions of that gentleman published after

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 1350000 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 $71\frac{1}{4}$ 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 $58\frac{6}{10}$ 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, *h c*; the angles E and *e* are preſſed down, and the beams EOF, *e o* F puſh up the point F. This cannot riſe without bending the beams EOF, *e o* 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 interſections 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.

17 For the bridge of Nogent,

Fig. 5. repreſents another, conſtructed by Perronet 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 row,

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 ſagging 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 Maxence, This maxim is better exemplified by Mr Perronet in the centering of the bridge of St Maxence, exhibited in fig. 5. n° 2. than in that of Nogent, fig. 5. n° 1. But we think that a horizontal truſs-beam *a b* 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 *c d*, *c d*, 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 $\frac{1}{14}$ or to $\frac{4}{7}$) 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 keyſtones 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. 20 Orleans.

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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 *a b*, 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 h 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 *a b*, 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 *a b* 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 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.

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22 All theſe centres good in their kind.

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.

23 Excellence of the centre employed for Blackfriars bridge.

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 it

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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.

24 Obſervations on the ſtate of an arch as it reſts on the centering.

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*.

25 A delicate buſineſs to ſtrike the centering.

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 ſoffet, 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. 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 Mautz. 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 $1\frac{1}{4}$ 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.

26 The foregoing obſervations exemplified.

In fig. 5. n° 1. may be obſerved an indication of this procedure of the maſonry. There may be noticed a horizontal line *a c*, and a diagonal *a b*. 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 A*b′ 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 mechanician 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 and *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 abſolutely 27 The connection that is formed by mortar of lime, &c.

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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 ſtrrong 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 together. 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 flewn 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.

29 Mr Perronet's conſtructions too bold.

30 A bad method of ſtriking the centre.

Mr Perronet mentions another mode of ſtriking the 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.

31 The common method in Britain.

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 malls. 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

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 stap of the pier; the ingenious contexture of which made it like one solid block of stone (see ARCH, *Supplement*). These struts

32 The excellence of Mr Mylne's method.

were gradually more and more oblique, till the outer one formed an obtuse angle with the lowest side of the interior polygon of the truss. 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 truss were mortised into a similar piece F, which may be called the SOLE of the truss, 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 truss 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 truss 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.

33 The great superiority of the centering used by him.

We have no hesitation in saying, that (if we except some 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 $1\frac{1}{4}$th inches, and about half an inch more when the parapets were added and the bridge completely finished.

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 rivalſhip 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 *d*C, *e*C, 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 C*f*, whoſe lower extremity *f* is carried by the ropes, rods, or wooden ties A*f*, B*f*. 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 *d*C*e*, or the equivalent angles AFB, or A*f*B, 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 *d*C, *e*C; 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 *a*F, *b*F, 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.

ftruts a F, b F are kept clear of it. No connection between them is neceffary, and it may be hurtful, by inducing crofs ftrains on both. It will, however, greatly increafe the ftiffnefs of the whole. This conftruction may fafely be loaded with ten times the weight that AB can carry alone.

36 An improvement of that method.

Suppofe this done, and that the fcantling of AB is too weak for carrying the weight which may be brought on the parts AC, CB. We may now trufs up each half, as in fig. 12. and then the whole will form a handfome bridge, of the fimpleft conftruction poffible. The interfections of the fecondary braces with thofe of the main trufs 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 diffuade from allowing any connection with the middle points of the main braces. This conftruction alfo may be followed till each beam AC and CB is loaded to ten times what it can fafely bear without the fecondary truffing.

37 Another method.

There is another way by which a bridge of one beam may be fupported beyond the power of the firft and fimpleft conftruction. This is reprefented in fig. 14. and fig. 15. The trufs beam FG fhould occupy one-third of AB. The advantage of this conftruction is very confiderable. The great elevation of the braces (which is a principal element of the ftrength) is preferved, and the braces are greatly fhortened.

This method may be pufhed ftill farther, as in fig. 16.

38 Thefe methods combined.

And all thefe methods may be combined, by joining the conftructions of fig. 14. and fig. 15. with that of fig. 16.

In all of them there is much room for the difplay of fkill, in the proper adjuftment of the fcantling of the timber, and the obliquity of the braces to the lengths of the different bearings. A very oblique ftrut, or a flender one, will fuffice for a fmall load, and may often give an opportunity to increafe the general ftrength; while the great timbers and upright fupports are referved for the main preffures. Nothing will improve the compofition fo much as reflecting progreffively, and in the order of thefe examples, on the whole. This alone can preferve the great principle in its fimplicity and full energy.

39 The elements of all that can be done in this art.

Thefe conftructions are the elements of all that can be done in the art of building wooden bridges, and are to be found more or lefs obvioufly and diftinctly in all attempts of this kind. We may affert, that the more obvioufly they appear, the more perfect the bridge will be. It is aftonifhing to what extent the principle may be carried. We have feen a bridge of 42 feet fpan formed of two oak truffes, the biggeft timber of which did not exceed fix inches fquare, bearing with perfect fteadinefs and fafety a waggon loaded with more than two tons, drawn by four ftout horfes. 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 Stettin, which feemed conftructed with great judgment and fpirit. It had a carrriage road in the middle about 20 feet (we think) wide, and on each fide a foot-way about five feet wide. The fpan was not lefs than 60 feet, and the greateft fcantling did not appear to exceed 10 inches by 6.

This bridge confifted of four truffes, two of which formed the outfide of the bridge, and the other two made the feparation between the carriage road and the two foot ways. We noticed the conftruction of the truffes very particularly, and found it fimilar to the laft, except in the middle divifion of the upper trufs, which, being very long, was double truffed, as in fig. 17.

The reader will find in that volume of Leupold's *Theatrum Machinarum*, which he calls *Theatrum Pontificum*, many fpecimens 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 confiders them *carefully*, will pick up here and there fubordinate hints, which are ingenious, and may fometimes be ufeful.

What we have now exhibited are not to be confidered as models of conftruction, but as elementary examples and leffons, for leading the reader fyftematically into a thorough conception of the fubject. 40

A wonderful bridge in Switzerland.

We cannot quit the fubject without taking notice of a very wonderful bridge at Wittengen in Switzerland, flightly defcribed by Mr Coxe (*Travels*, vol. I. 132.) It is of a conftruction more fimple ftill than the bridges we have been defcribing. The fpan is 230 feet, and it rifes only 25. The fketch (fig. 18.) will make it fufficiently intelligible. ABC is one of two great arches, approaching to a catenarian fhape, built up of feven courfes of folid logs of oak, in lengths of 12 or 14 feet, and 16 inches or more in thicknefs. Thefe are all picked of a natural fhape, fuited to the intended curve; fo that the wood is nowhere cut acrofs the grain to trim it into fhape. Thefe logs are laid above each other, fo that their abutting joints are alternate, like thofe of a brick wall; and it is indeed a wooden wall, fimply built up, by laying the pieces upon each other, taking care to make the abutting joints as clofe as poffible. They are not faftened together by pins or bolts, or by fcarfings of any kind. They are, however, held together by iron ftraps, which furround them, at the diftance of five feet from each other, where they are faftened by bolts and keys.

Thefe two arches having been erected (by the help, we prefume, of pillars, or a centering of fome kind), and well butted againft the rock on each fide, were freed from their fupports, and allowed to fettle. They are fo placed, that the intended road abc interfects them about the middle of their height. The roadway is fupported by crofs joifts, which reft on a long horizontal fummer beam. This is connected with the arches on each fide by uprights bolted into them. The whole is covered with a roof, which projects over the arches on each fide to defend them from the weather. Three of the fpaces between thefe uprights have ftruts or braces, which give the upper work a fort of truffing in that part.

This conftruction is fimple and artlefs; and appears, by the attempt to trufs the ends, to be the performance of a perfon ignorant of principle, who has taken the whole notion from a ftone arch. It is, however, of a ftrength much more than adequate to any load that can be laid on it. Mr Coxe fays, but does not explain how, that it is fo contrived that any part of it can be repair-

ed

ed independent of the reft. It was the laft work of one Ulrich Grubenhamm of Tuffen, in the canton of Appenzel, a carpenter without education, but celebrated for feveral works of the fame kind; particularly the bridge over the Rhine at Schafhanfen, confifting of two arches, one of 172 and the other of 193 feet fpan, both refting on a fmall 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 fimple notion of Grubenhamm's is mightily improved. The fpan of the arch was faid to exceed 250 feet, and its rife exceedingly fmall. The defcription we got is very general, but fufficient, we think, to make it perfectly intelligible.

41 Another in North America.

In fig. 19. DD, EE, FF, are fuppofed to be three beams of the arch. They confift of logs of timber of fmall lengths, fuppofe of 10 or 12 feet, fuch as can be found of a curvature fuited to its place in the arch without trimming it acrofs the grain. Each beam is double, confifting of two logs applied to each other, fide to fide, and *breaking joint*, as the workmen term it. They are kept together by wedges and keys driven through them at fhort intervals, as at K, L, &c.

The manner of joining and ftrongly binding the two fide pieces of each beam is fhewn in fig. 20. The mortife *a i c b* and *d c i o*, which is cut in each half beam, is confiderably longer on the outfide than on the infide, where the two mortifes meet. Two keys, BB and CC, are formed, each with a notch *b c d*, or *a i o*, on its fide; which notch fits one end of the mortife. The inner fide of the key is ftraight, but fo formed, that when both keys are in their places, they leave a fpace between them wider at one end than the other. A wedge AA, having the fame taper as the fpace juft mentioned, is put into it and driven hard. It is evident that this muft hold the two logs firmly together.

This is a way of uniting timber not mentioned in the article Carpentry; and it has fome peculiarities worthy of notice. In the firft place, it may be employed fo as to produce a very ftrong lateral connection, and would then co-operate finely with the other artificial methods of fcarfing and tabling that we defcribed in the article referred to. But it requires nice attention to fome circumftances of conftruction to fecure this effect. If the joints are accurately formed to each other, as if the whole had been one piece divided by an infinitely thin faw, this manner of joining will *keep* them all in their places. But no driving of the wedge AA will make them firmer, or caufe one piece to prefs hard on the other. If the abutment of two parts of the half beam is already clofe, it will remain fo; but if open in the fmalleft degree, driving of the wedge will not make it tighter. In this refpect, therefore, it is not fo proper as the forms defcribed in Carpentry.

In order that the method now defcribed may have the effect of *drawing* the halves of the beams together, and of keeping them hard fqueezed on each other, the joints muft be made fo as not to correfpond exactly. The prominent angle *a i o* (fig. 21.), formed by the ends of the two half mortifes, muft be made a little more obtufe than the angle *a f o* of the notch of the key which this prominence is intended to fill up. Moreover, the oppofite fide *e t* of this key fhould not be quite ftraight, but a very little convex. With thefe precautions, it is eafy to fee that, by driving the wedge AA, we caufe the notch *a f o* to take hold, firft at the two points *a* and *o*, and then, by continuing to drive the wedge, the fides *a f*, *o f*, of the notch gradually comprefs the wood of the half beams, and prefs them on each other. By continuing to drive the wedge, the mutual compreffion of the key and the beam fqueezes all together, and the fpace *a f o i* is completely filled up. We may fee, from this procefs, that the mutual compreffion and drawing together of the timber will be greater in proportion as we make the angle *a i o* more prominent, and its correfponding angle *a f o* more deep; always taking care that the key fhall be thick enough not to break in the narrow part.

This adjuftment of the keys to the mortife is neceffary on another account. Suppofing the joints to fit each other exactly before driving the wedge, and that the whole fhrinks a little by drying—by this the angle *a i o* will become more prominent, and the angle *a f o* will become more fhallow; the joint will open at *a* and *o*, and the mutual compreffure will be at an end.

We may alfo obferve, that this method will not give any additional firmnefs to the abutments of the different lengths employed to piece out the arch-beam; in which refpect it differs materially from the other modes of joining timber.

Having fhewn how each beam is pieced together, we muft now fhew how a number of them are united, fo as to compofe an arch of any thicknefs. This is done in the very fame way. The beams have other mortifes worked out of their inner fides, half out of each half of the beam. The ends of the mortifes are formed in the fame way with thofe already defcribed. Long keys BB, CC, (fig. 19.) are made to fit them properly, the notches being placed fo as to keep the beams at a proper diftance 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 fpan, and made of any thicknefs of arching. The bridge over Portfmouth river in North America was more than 250 feet in length, and confifted of feveral parallel arches of beams. The inventor (we think that his name is Bludget) faid that he found the ftrength fo great, that he could with perfect confidence make one of four times the fpan.

We admire the ingenuity of this conftruction, and think it very effectual for bringing the timbers into firm and uniform abutment; but we imagine that it requires equilibration, becaufe it is extremely flexible. There is nothing to keep it from bending, by an inequality of load, but the tranfverfe ftrength of the beams. The keys and wedges can have very little power to prevent this bending. The diftance between the beams will alfo contribute little or nothing to the ftiffnefs; nay, we imagine that a great diftance between them will make the frame more flexible. Could the beams be placed fo near each other that they could be fomehow joggled on each other, the whole would be ftiffer; but at prefent they will bend like the plates of a coach-fpring. But nothing hinders us from adding diagonal pieces to this conftruction, which will give it any degree of ftiffnefs, and will enable it to bear any inequality of loading. When completed in this manner, we imagine that it will be at leaft equal to any conftruction that has yet been thought of. One advantage it poffeffes that is very precious: Any piece that fails

may

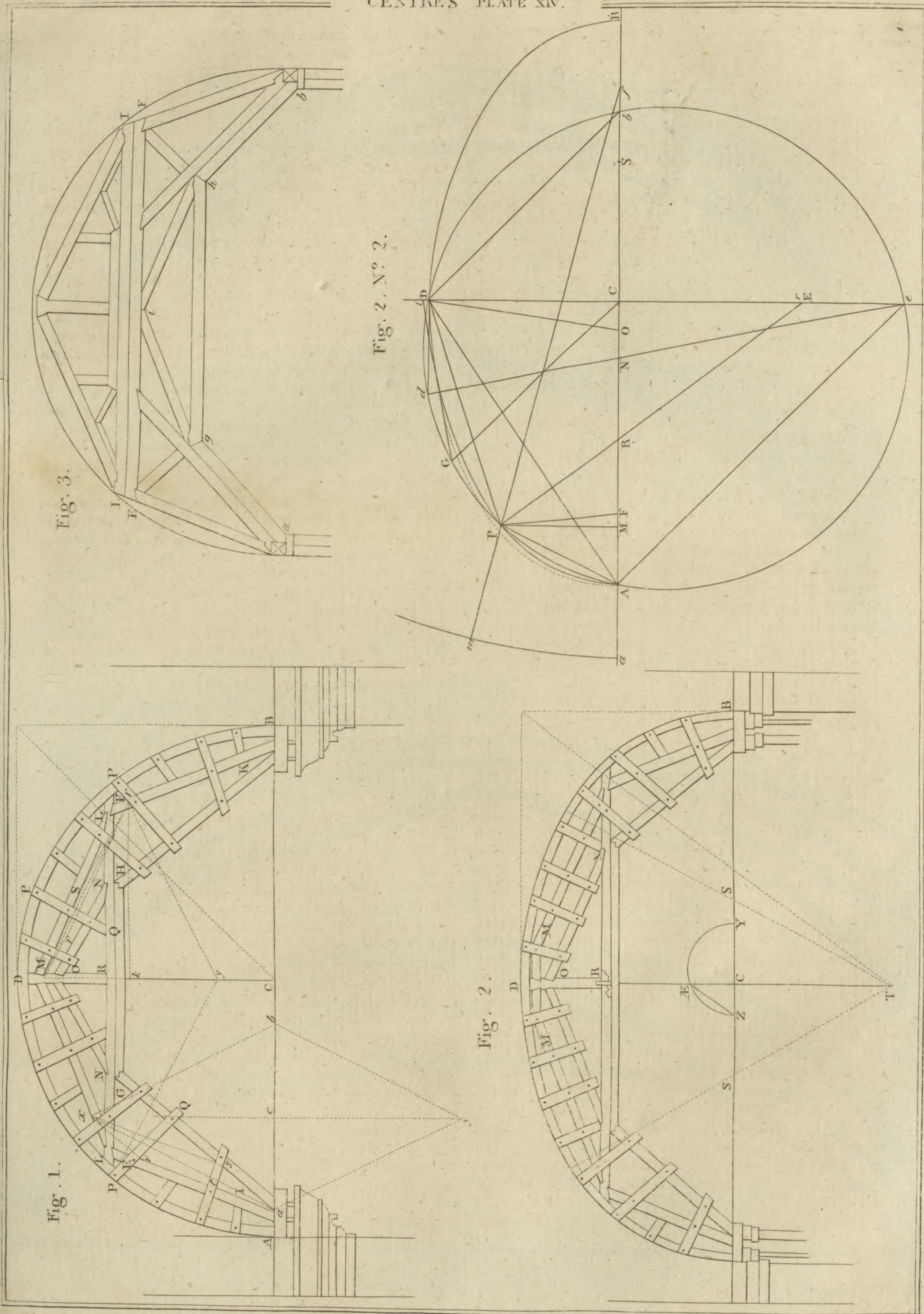


Fig. 1.
Fig. 2.
Fig. 3.
Fig. 2. N°. 2.

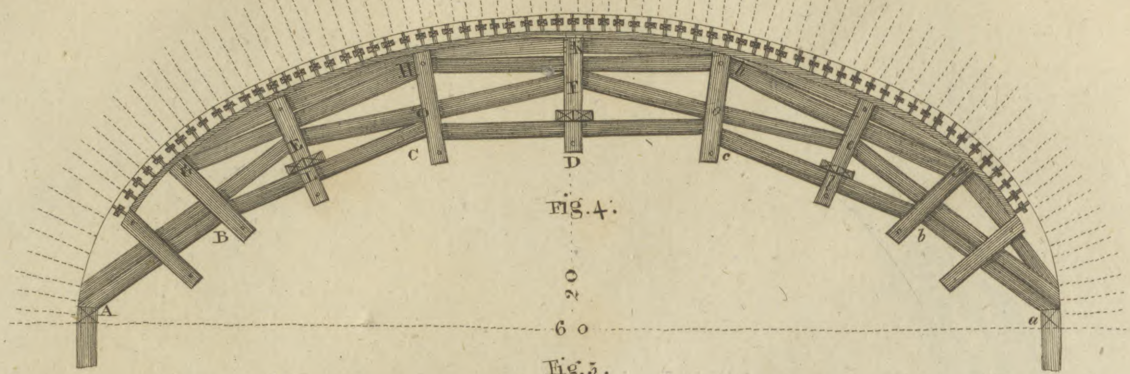


Fig. 5.

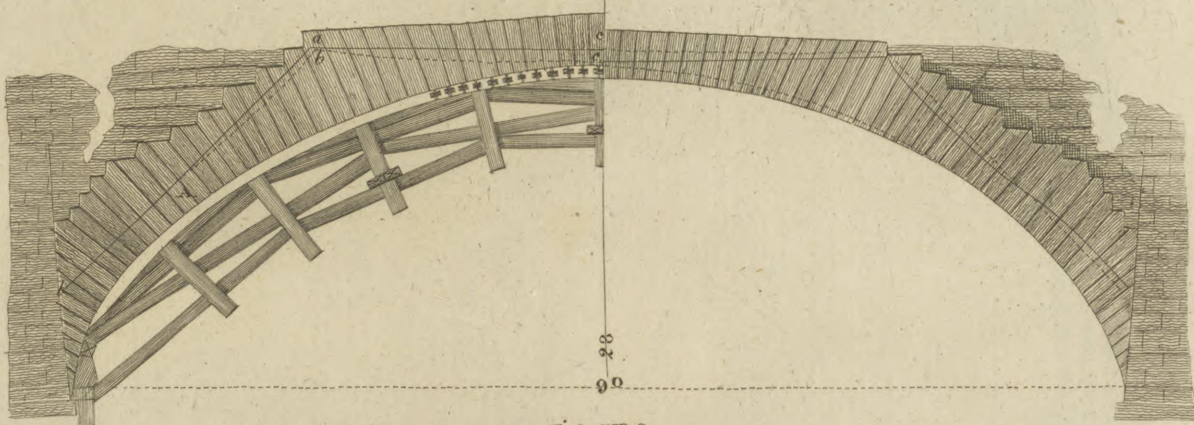
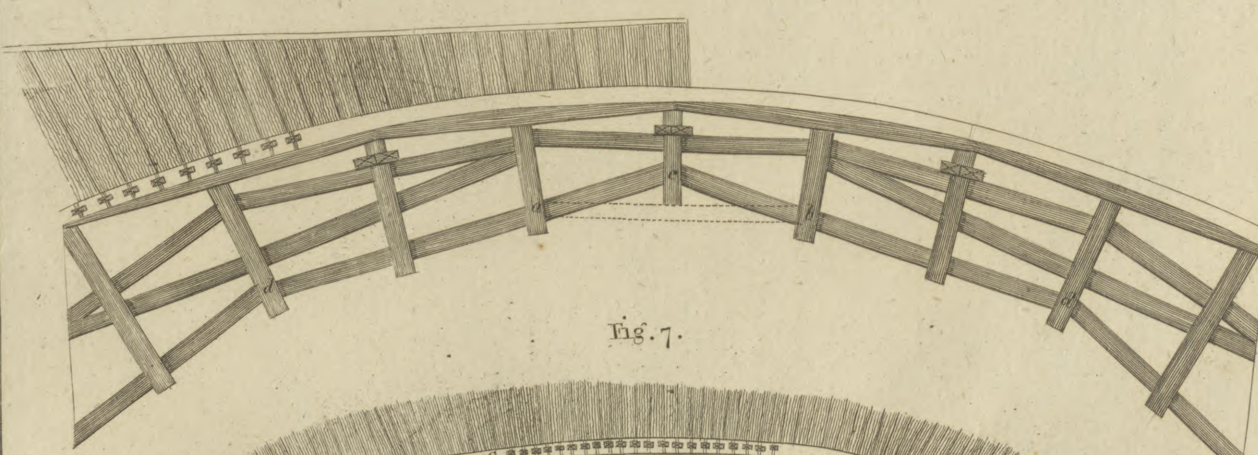
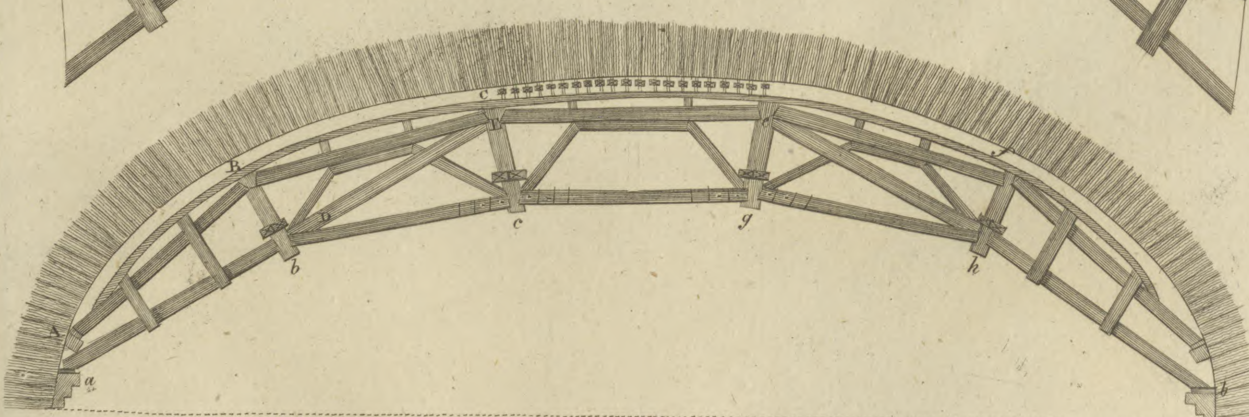


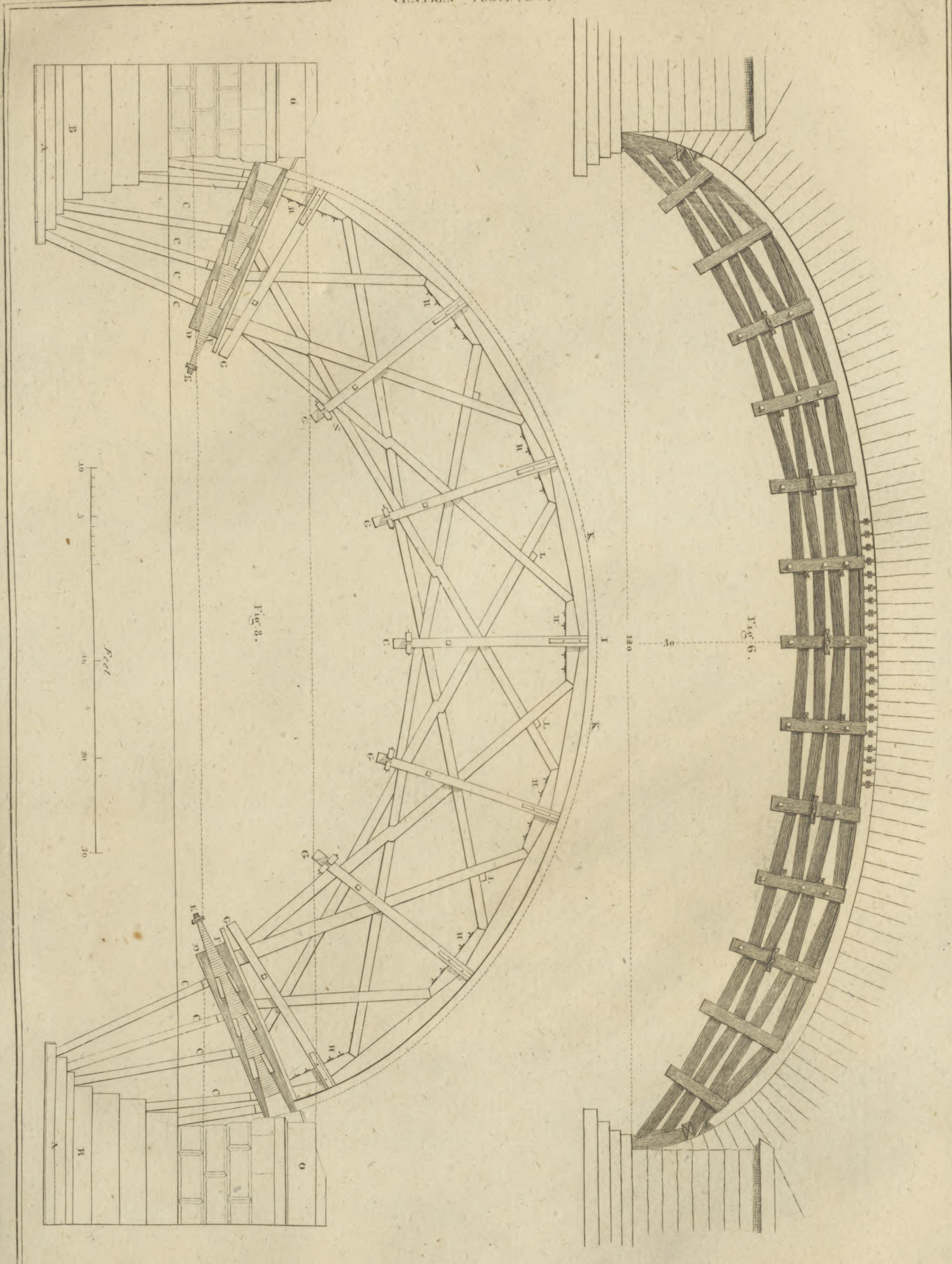
Fig. 5. No. 2.



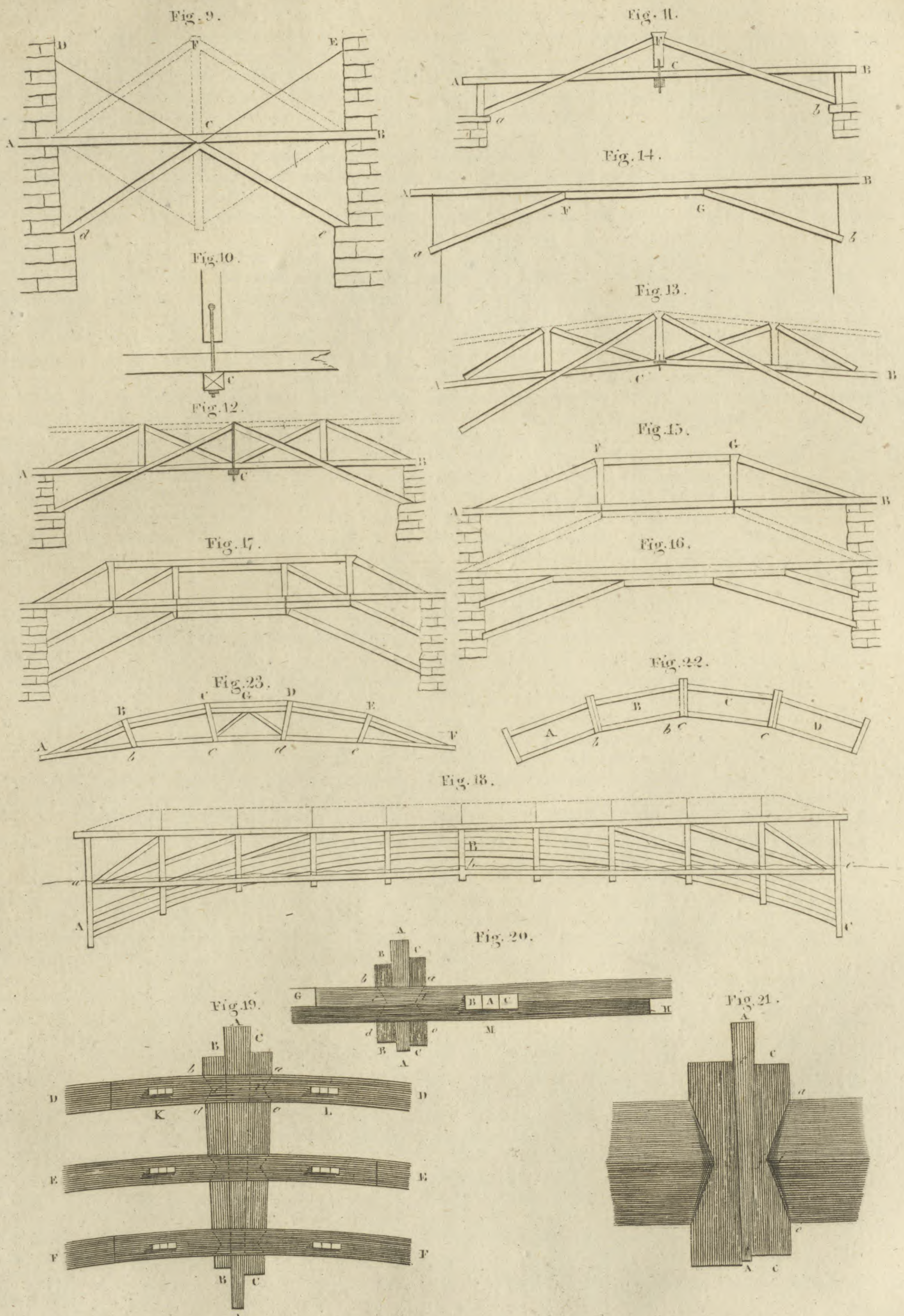


D. Lizars Sculp.t

CENTRES PLATE XVI.



D. Lizars Sculp.



Olliers sculp.

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 composition.

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 attention 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.

43 How to distinguish bridges formed according to these different methods.

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 of 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 potass. 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. Somerset-house was worth to him at least L. 2000 a-year. His *Chef d'œuvres* are his staircases, particularly those at Lord Besborough's, Lord Gower's, and the Royal and Antiquarian Societies. The terrace behind Somerset-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 Iunis, 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 small 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 Literaire*, 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 journalist, 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*.

"I

"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*,	—	ſee,
(2)	$\cdot 5$	=	*perfect tenſe*,	—	ſaw,
(3)	$:5$	=	*perfect participle*,	—	ſeen,
(4)	$5:$	=	*preſent participle*,	—	ſeeing,
(5)	$5\cdot$	=	*future*,	— —	will ſee,
(6)	$\underline{5}$	=	*ſubſtantive*,	—	ſight,
(7)	$\underline{\underline{5}}$	=	*perſonal ſubſtantive*,	—	ſpectator,
(8)	6	=	*nominative caſe*,	—	a man,
(9)	$\ddot{6}$	=	*genitive*,	— —	of a man,
(10)	$\dddot{6}$	=	*dative*,	— —	to a man,
(11)	$\overset{\frown}{6}$	=	*feminine*,	— —	a woman,
(12)	$+6$	=	*plural*,	— —	men,
(13)	7	=	*poſitive*,	— —	happy,
(14)	$\hat{7}$	=	*comparative*,	—	happier,
(15)	$\hat{\hat{7}}$	=	*ſuperlative*,	—	happieſt,
	$\underline{7}$	=	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:

$9, 8, .5, -\hat{7}, \overset{\frown}{6}$. *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*.

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, $\overset{4}{6943}$; 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.

CHAUSETRAPPES. 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. IS 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. Indeed, 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 really 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 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; reſerving 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. 3 Arrangement.

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 decompounded. 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. ALL the bodies which are at preſent reckoned ſimple, becauſe they have never been decompounded, may be reduced into ſix claſſes.

1. Oxygen,
2. Simple combuſtibles,
3. Metals,
4. Earths,
5. Caloric,
6. Light.

Theſe ſhall form the ſubjects of the ſix following chapters.

CHAP. I. *Of* OXYGEN.

Plate XVIII. TAKE 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 5 Method of procuring oxygen.

ing

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 Diſcovered by Prieſtley and Scheele.

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 tub 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 common air. Like it too, it is elaſtic, and capable of indefinite expanſion and compreſſion.

9 Supports flame,

2. If a lighted taper be let down into a jar of oxgen 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.

10 And life.

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.

11 Exiſts in the atmoſphere.

4. Atmoſpherical 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.

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 atmospherical air is as 1103 to 1000: 116 cubic inches of oxygen gas weigh 39,03 grains troy, 116 cubic inches of common air, 35,38 grains.

* On *Phlogiston*, sect. i.

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,

Sirit 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. 14 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 *particulæ igneo-aereæ*. He knew that this part was contained in nitre: "Pars nitri aerea nihil aliud quam particulæ ejus igneo-aereæ 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 *Tractatus 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 necessareas 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.

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 decompounded. 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 decompounded: 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.

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†.

† Fourcroy.

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 congeals‡.

‡ Dr Black.

17 Flowers of sulphur.

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*.

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.

19 Converted by combustion into an acid.

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.

20 Stahl's explanation of this.

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 incombustbile 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.

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 potass* is a substance composed of sulphuric acid and potass (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 *potass* and *sulphat of potass*, 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 potass and sulphur combined together,

(D) The nature of *potass* 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, potass, 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 Unsatisfactory. 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 explanation 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. 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 potass and sulphur produced by Stahl's experiment, we find them to be considerably lighter than the charcoal, sulphuric acid, and potass 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 alkalies,
Ammonia,
Barytes,
Lime,
Magnesia,
Phosphorus?
Oils,
Ether,
Alcohol.

Sect. II. *Of Phosphorus.*

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 24 Production of phosphorus.

(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*.

Phosphorus 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.

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 †.

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 ‡.

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.

* Leibnitz, Melange de Berlin.

† Stahl's Three Hundred Experiments.

‡ Boyle Abridged by Shaw, iii. 174.

‖ Bergman's Notes on Scheffer.

26 Its properties.

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 twisted to pieces with the fingers. It is insoluble in water. Its specific gravity is 1,714.

It melts at the temperature of 99° *, and even at 67° 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 ‡.

* Pelletier, Journal de Physique, xxxv. 380.

† 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;

(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 Transl. 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.

29 Which is phoſphorus combined with oxygen.

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).

* *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. / 18 Sulphur	congeals at	59°
72 Phoſphor. / 36 Sulphur	at	50°
72 Phoſphor. / 72 Sulphur	at	41°
72 Phoſphor. / 216 Sulphur	at	99°

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*.

31 Properties of 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.

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 atmoſpherical 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. 309.

† *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.*

32 Converted into an acid.

‖ *Mem. Acad.* 1781, p. 448.

33 Suſceptible of cryſtallization.

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,

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(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.

pected, 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 $2\frac{1}{4}$ 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 Petersburgh 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 with them compounds known by the name of *carburets*. 35 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 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). 36 Method of procuring hydrogen.

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 §; 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 three produced extreme feebleness and oppression about the breast ‖.

§ Scheele on Fire.

‖ Jour de Phys. xv. 99.

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

(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 atmoſpherical 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.

* *Encycl. Method. Chim.* i. 754.
† *Ann. de Chim.* i. 192.
‡ *Jour. de Phyſ.* xxxvi. 412.

39
Compounds of hydrogen gas.

Hydrogen gas diſſolves ſulphur, phoſphorus, and carbon. The compounds are called *ſulphurated*, *phoſphorated*, and *carbonated hydrogen gas*.

40
Sulphurated hydrogen 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 potaſs be melted together in a covered crucible, they combine together, and form a compound known by the name of *ſulphuret of potaſs*, 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. iii.

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 †. It does not ſeem capable of exiſting in atmoſpherical air without decompoſition; for the moment it comes into contact with oxygen gas, ſulphur is depoſited ‡.

† *Fourcroy's Chemiſtry*, art. Sulphur
‡ *Bergman.*

41
Phoſphorated hydrogen gas.

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 potaſs 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.

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. 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.

§ *Kirwan.*

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.

42
Carbonated hydrogen gas.

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 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

¶ *Ann. de Chim.* xxi. 48.

(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 ὑδωρ *water*, and γινομαι *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*.

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.

† Ibid.

43 Affinities of these gases.

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.

44 Attempt to decompose carbon

‡ Phil. Transf. lxxx. 51.

45 Examined,

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 decompounded by the electric shocks.

§ Phil. Transf. 1797 part 2d.

Azot.

46 And found unsuccessful.

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 potass, 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 decompounded 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 709 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.

47 Affinities of hydrogen.

The affinities of hydrogen have not yet been ascertained, but perhaps they are as follows:

Oxygen,
Carbon,
Azot.

Sect. V. *Of Azot.*

48 Method of procuring 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.

49 Discovery of 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 ,73 parts of azotic gas; almost all the rest is oxygen gas. The easiest method of procuring azotic gas is to put some sulphuret of potass 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*.

* Nicholson's Journal, i. 268.

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†.

† On Phlogiston § 1st.

50 Its properties.

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 (T). 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 §.

‡ Fourcroy, Ann. de Chim. i. 45.

§ Nicholson's Journal, ii. 8.

Azotic gas is capable of dissolving phosphorus, as has been proved by the experiments of Fourcroy and Vauquelin.

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, deposites on the sides of them a black matter which has the properties of carbon *.

* Fourcroy, Ann. de Chim. i. 45.

These two solutions, the properties of which have not yet been accurately examined, are called *phosphorated and carbonated azotic gas.*

51 Production of nitric acid.

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 bason 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).

52 Attempts to decompose azot.

The affinities of azot are still unknown. It has never yet been decompounded, 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 combus-

(s) See his thesis *De Aere Mephitico*, published in 1772.—" Sed aer salubris et purus respiratione 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 respiratione 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 urinæ 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.

(T) Hence the name *azot*, given it by the French chemists, which signifies *destructive to life*, from α 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.

combustible (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 decompound 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.

54 Properties of metals.

Metals may be considered as the great instruments 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.

55 Lustre.

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.

56 Opacity.

2. They are absolutely opaque, or impervious to light, even after they have been reduced to very thin plates. Silver leaf, for instance, $\frac{1}{160000}$ of an inch thick, does not permit the smallest ray of light to pass throught it. Gold, however, may be rendered transparent; for gold leaf, $\frac{1}{280000}$ 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 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.

* Nicholson's Notes on Fourcroy.

57 Fusibility.

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.

58 Gravity.

4. Their specific gravity is greater than that of any other body hitherto discovered.

5. They are better conductors of electricity than any other body.

59 Malleability.

6. But one of their most important properties is *malleability*; by which is meant the capacity of being 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 inserviit, 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 ſoot of thoſe chimneys under which metals have been calcined.

62 Stahl's theory of the compoſition of metals

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.

65 Farther improved.

66 Still imperfect.

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).

* *Fire and flame weighed.*

67 Refuted by Lavoiſier.

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 air

(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.

Metals. 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 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 decompounded.

* Jour. de Phys. 1785.

68 Oxide and oxidation, what.

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.*

69 Number of metals.

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, chromum.

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 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 mercurials, 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 essuyée, *mais a sa combinaison intime avec le fluide elastique*, dont le poids ajouté a celui du mercure est la seconde cause de l'augmentation de pesanteur qu'on observe dans les precipités que j'ai soumis a 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 $56\frac{3}{4}$ square inches. These leaves are only $\frac{1}{282000}$ of an inch thick. But the gold leaf with which silver wire is covered has only $\frac{1}{12}$ 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 pounds without breaking *.

* *Macquer's Dict.*

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 for some hours to the utmost heat of Mr Parker's lens †. Mr Lavoisier, however, observed, that a piece of silver, held over gold melted by a fire blown by oxygen gas, which produces a much greater heat than common air, was sensibly *gilt*: Part of the metal, then, must have been volatilized.

† *Kirwan's Miner.* i. 92.

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 potass 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 *, are as follows:

* *Bergman on Elective Attractions, Opusc.* t. 3.

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 alchymists, was the king of metals); it is now called *nitro-muriatic acid.*

Silver.

Tartarous,
Phoſphoric,
Sebacic,
Pruſſic,
Fixed alkali (D),
Ammonia.

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 $\frac{1}{160000}$ of an inch thick, and drawn into wire much finer than a human hair.

Its tenacity is ſuch, that a wire of ſilver, $\frac{1}{10}$th of an inch in diameter, is capable of ſuſtaining 270 pounds without breaking ‡.

Its hardneſs is 6,5 §. 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 ¶.

‡ *Macquer's Dict.*
§ *Kirwan.*
‖ *Briſſon.*
¶ *Kirwan's Mineral.* ii. 107.

The experiments of the French academicians have proved that it may be volatilized, but that it requires a very violent heat.

When cooled ſlowly, it aſſumes a cryſtalline form. Tillet and Mongez obtained it in quadrangular pyramidal cryſtals, both inſulated and in groups.

74 Oxides of ſilver.

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 potaſs, 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:

* *Macquer's Dict.*
† *Kirwan's Miner.* ii. 493.

Muriatic acid,
Sebacic,
Oxalic,
Sulphuric,
Saccholactic,
Phoſphoric,
Sulphurous,
Nitric,
Arſenic,
Fluoric,
Tartaric,
Citric,
Formic,
Lactic,
Acetous,
Succinic,
Pruſſic,
Carbonic,
Ammonia.

75 Sulphuret of ſilver.

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, $\frac{15}{100}$ ‡. 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.

‡ *Ibid.* 492.

76 Phoſphuret of ſilver.

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 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 *glaſs*, becauſe they acquire a good deal of reſemblance, in ſome particulars, to common glaſs.

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.* xiii. 110.

Silver does not seem capable of combining with carbon.

77 Alloys of silver.

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. *Allay.*

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 *.

* *Ann. de Chim.* i. 142.

79 Its affinities.

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.*

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 (I).

80 Discovery of platinum.

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*,

(H) Metals combined together are called *alloys* or *allays*.

(I) 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 cinxit ebur, trabibus solidatur ahenis
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.—Ubicunque quinta argenti portio est, *electrum* vocatur. Scrobes eæ reperiuntur in Canaliensi. Fit et cura electrum argento addito. Quod si quintam portionem excessit, incudibus non restitit. Et electro auctoritas, Homero teste, qui Menelai regiam auro, electro, argento, ebore 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 cœlestibus similes cum igneo stridore, et gemina ratione prædicunt."—*Lib.* xxxiii. *cap.* iv.

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 (K). 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 $\frac{1}{1940}$ of an inch in diameter. This wire admitted of being flattened, and had more strength than a wire of silver or gold of the same size *.

* *Withering.*

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.

Its hardness is 7,5 †. Its specific gravity, after being hammered, is 23,000; so that it is by far the heaviest body known.

† *Kirwan's Miner.* ii. 103.

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 nitro-muriatic acid, and precipitating it by means of an earth or potass. 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 $\frac{1}{47}$ 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 keeping 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.

Sect. IV. *Of Mercury.*

Mercury. Mercury, called also *quicksilver*, was known to the ancients, and seems to have been employed by them in gilding.

84 Properties of mercury. 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.

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 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°.

† See *Macnab's Experiments, Phil. Trans.*

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.

85 It forms three oxides; 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*.

86 The black oxide, 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.

87 Yellow 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 potass 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 ‡.

‡ *Kirwan's Miner.* ii. 489.

88 And red 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;

(K) 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)?
Saccholactic,
Tartarous,
Citric,
Sulphurous,
Nitric,
Fluoric,
Zoonic (M)?
Acetous,
Boracic,
Prussic,
Carbonic.

90 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 potass 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 potass, 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 gelly, 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*. Count De Moussin 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†.

* Nicholson's Journ. ii. 1.

† 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 Phosphuret of mercury.

Mr Pelletier, after several unsuccessful attempts to form phosphuret of mercury, at last succeeded by distilling 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 exhaled vapours of phosphorus ‡.

‡ Ann. de Chim. xiii. 122.

Mercury does not seem capable of combining with carbon.

93 Its amalgams.

The combinations of mercury with the other metals are called *amalgams*.

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 Dict 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 Moussin Pouschin. 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.*

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.

95 Properties of copper.

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 $\frac{1}{10}$ of an inch in diameter can sustain a weight of $299\frac{1}{4}$ pounds without breaking*.

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 ‖.

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.

* Macquer's Dict.
† Kirwan's Miner ii. 127.
‡ Brisson.
§ Keir's Notes on Macquer's Dict.
‖ Bergman, ii. 263.

96 Brown oxide of copper.

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 *.

* Kirwan's Miner. ii. 487.

97 Blue and green oxides.

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 †.

† Fourcroy iii. 101.

98 Their affinities.

The affinities of the oxides of copper, according to Bergman, are as follows:

Pyro-mucous acid ‡
Oxalic,
Tartarous,

‡ Schrickel.

(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.

Tartarous,
Muriatic,
Sulphuric,
Saccholactic,
Nitric,
Sebacic,
Arsenic,
Phosphoric,
Succinic,
Fluoric,
Citric,
Formic,
Lactic,
Acetous,
Boracic,
Prussic,
Carbonic,
Fixed alkalies,
Ammonia,
Fixed oils.

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 and 19 of sulphur *.

* *Kirwan's Miner.* ii. 508.

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 §.

† *Ann. de Chim.* i. 74.

‡ *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.

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.

102
Its affinities

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.

Sect. VI. *Of Iron.*

103
Discovery of iron.

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. 9.
‡ Numb. xxxv. 16.
§ Levit. i. 17.
|| Deut. xviii. 5.
¶ *Ibid.* xxvii. 5.

* *Hesiod*, as quoted by *Pliny*, lib. vii. c. 57.

(R) Αυταρ Πηλειδης θηκεν σολον αυτοχοωνον,
Ὁν πριν μεν ριπτασκε μεγα σθενος Ηετιωνος·
Αλλ' ητοι τον επεφνε ποδαρκης διος Αχιλλευς,

Τον

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
Its 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 pounds without breaking *.

* *Macquer's Dict.*

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 †.

The *green oxide* may be obtained by diſſolving iron in ſulphuric acid, and then precipitating it by potaſs. 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.

† *Ann. de Chim.* xxiii. 85. and *Nicholſon's Journal*, i. 453.

‡ *Mem. Acad. Par.* 1782.

106
Their affinities.

The affinities of theſe oxides, according to Bergman, are as follows:

Gallic acid?
Oxalic acid,
Tartarous,
Camphoric §,
Sulphuric,
Saccholactic,
Muriatic,
Pyromucous ||,
Nitric,
Sebacic,
Phoſphoric,
Arſenic,
Fluoric,
Succinic,
Citric,
Formic,
Lactic,
Acetous,
Boracic,
Pruſſic,
Carbonic.

§ *La Grange.*

|| *Schrickel.*

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° Wedgewood 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
Phoſphuret,

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

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Τον δ' αγετ' εν νηεσσι συν αλλοισι κτιατεσσι.
Στη δ' ορθος, και μυθον εν Αργειοισιν ειπεν·
Ορνυσθ', οἱ και τȣτȣ αεθλȣ πειρησεσθε·
Ει οἱ και μαλλα πολλον αποπροθι πιονες αγροι,
Ἑξει μιν και περιπλομενȣς ενιαυτȣς
Χρεωμενος· ȣ μεν γαρ οἱ ατεμβομενος γε σιδηρȣ
Ποιμην, ȣδ' αροτηρ, εισ' ες πολιν, αλλα παρεξει. Iliad, xxiii. l. 826.

Iron.

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 phospuret 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.

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*.

111 Wrought iron.

Wrought Iron is the substance which we have been hitherto describing. As it has never yet been decompounded, 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* *.

* Dr Pearson on Wootz, *Phil. Trans.*

113 Cast 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 †.

† *Ibid.*

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 ‡.

‡ Beddoes, *Phil. Trans.* 1791.

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.

114 Cause of these varieties.

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.

§ *Pliny*, l. xxxiv. 14.

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,

(s) This process in chemistry is called *reduction*.

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 $\frac{1}{45}$; from 100 parts of ſteel, 0,5, or $\frac{1}{200}$; and from 100 parts of wrought iron, 0,12, or $\frac{1}{800}$. Now plumbago is compoſed of $\frac{9}{10}$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.

* *Morveau, Encycl. Method. Chimie*, i. 448.

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 $\frac{1}{150}$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 proportion 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 (T).

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:

* *Jour. des Mines.* See *Nicholſon's Journal*, i. 200

115 Vauquelin's analyſis of ſteel.

Firſt ſteel, compoſed of	Carbon,	0,00789
	Silica,	0,00315
	Phoſphorus,	0,00345
	Iron,	0,98551
		1
Second ſteel, compoſed of	Carbon,	0,00683
	Silica,	0,00273
	Phoſphorus,	0,00827
	Iron,	0,98217
		1
Third ſteel, compoſed of	Carbon,	0,00789
	Silica,	0,00315
	Phoſphorus,	0,00791
	Iron,	0,98105
		1
Fourth ſteel, compoſed of	Carbon,	0,00631
	Silica,	0,00252
	Phoſphorus,	0,01520
	Iron,	0,97597
		1

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.

116 Alloys of iron.

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 metals

(T) An earth which ſhall be deſcribed in the next chapter.

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 *.

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?

* Ann. de Chim. vi. 39.

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 ‡.

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 *tinfoil* as it is called, is about $\frac{1}{1000}$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.

Its hardness is 6 ‖. Its specific gravity is 7,291; after hammering, 7,299 ¶.

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 *.

† Pliny, l. 4. c. 34. and l. 34. c. 47.

‡ Numbers, xxxi. 22.

§ Macquer's Dictionary.

‖ Kirwan's Miner. ii. 195.

¶ Brisson.

* Pajot, Jour. de Phys. xxxviii. 52.

119
Oxides,

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.

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 †.

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.

* Geoffroy.

† Kirwan's Miner. ii. 488.

‡ Schrickel.

120
Sulphurets,

Tin combines readily with sulphur. This sulphuret 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 §.

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*. It is a mass consisting of beautiful gold-coloured flakes, and is used as a paint. It is composed of about 40 parts of sulphur and 60 of white oxide of tin ¶. The process 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 *.

§ Ann. de Chim. xiii. 287.

‖ Pelletier, Ibid. p. 297.

¶ Ibid. 293.

* See his Memoire, Ann. de Chim. xiii. 280.

121
Phosphuret,

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 with the

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 laminæ. 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.

* Ann. de Chim. xiii. 116.

122 Alloys. 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 $\frac{1}{17}$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.

† Alchorne, Phil. Tranſ.

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‡.

‡ Dr Lewis.

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, $\frac{1}{10}$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 *æs* of the Romans, was nothing elſe. Even their copper coins contain a mixture of tin §.

§ See Dizé's Analyſis, Jour. de Phyſ. 1790.

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 dipt into melted tin. This is the method of making *tinplate*.

123 And affinities of tin. 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. 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. 124 Properties of lead.

It is very malleable, and may be reduced to thin plates by the hammer; but its ductility is very imperfect: a wire of lead $\frac{1}{10}$th of an inch in diameter is only capable of ſupporting a weight of $29\frac{1}{4}$ pounds*.

* Macquer's Dictionary.

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.

† Kirwan's Miner. ii. 202.

‡ Briſſon.

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 concourſe of ſix quadrangular pyramids §.

§ Jour. de Phyſ. xxxviii. 53.

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: 125 Its oxides.

‖ Kirwan's Miner. ii. 499.

Sulphuric acid,
Sebacic,
Saccholactic,
Oxalic,
Arſenic,
Tartarous,
Phoſphoric,
Muriatic,

Benzoic,

Lead.

Benzoic (υ)?
Sulphurous,
Suberic?
Zoonic? } (*v*)
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.

126 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 of ſulphur †.

† *Kirwan's Miner.* ii. 492.

127 Phoſphuret,

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.

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 Academicians.*

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.

129 Affinities.

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?

130 Names and marks given to the metals by the ancients.

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.

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

(υ) 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 Mithraciſque 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, 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. "The character of Mars (he obſerves*), according to the oldeſt mode of repreſenting it, is evidently an abbreviation of the word Θουρος, under which the Greek mathematicians underſtood that deity; or, in other words, the firſt letter Θ, with the laſt letter ς placed above it. The character of Jupiter was originally the initial letter of Ζευς; and in the oldeſt manuſcripts of the mathematical and aſtrological works of Julius Firmicus, the capital Z 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 Φωσφορος, which was the name of that goddeſs. The imaginary ſcythe of Saturn has been gradually formed from the two firſt letters of his name Κρονος, 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 Στιλβων, 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 ◠, 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."

* *Hiſtory of Inventions, Engliſh tranſlation*, iii. 67.

Zinc.

Sect. IX. *Of Zinc.*

134 Diſcovery 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

* *Pliny*, l. 34. c. 2. and 10.

ſtannea, tertia ex ære, quarta ferrea, quinta ex ære mixto, ſexta argentea, ſeptima ex auro. Κλιμαξ ὑψιπυλος, επι δ' αιτη πυλη ογδοη. Ἡ πρωτη των πυλων μολιβδου, ἡ δευτερα κασσιτερου, ἡ τριτη χαλκου, ἡ τεταρτη σιδηρου, ἡ πεμπτη κερασου νομισματος, ἡ ἑκτη αργυρου, χρυσου δ' ἡ ἑβδομη. 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 mollitiem; tertiam Veneris æratam et ſolidam; quartam Martis, eſt enim laborum patiens, æque ac ferrum, celebratus hominibus; quintam Mercurii propter miſturam 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.

Zinc.

had a yellow colour (Y). 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*.

* See Vol. vi. of his Works in 4to.

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 †.

† Bergman, ii. 309.

135 Properties of zinc.

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.

‡ Sage.

Its hardness is 6 §. Its specific gravity, when compressed, is 7,1908 ‖; in its usual state, 6,862 ¶. It melts at about 699° Fahrenheit *.

§ Kirwan's Miner. ii. 232

‖ Brisson.

¶ Kirwan, ibid.

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 †.

* Bergman.

† Mongez.

136 Its oxides,

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).

‡ Morveau, Kirwan's Miner. ii. 489.

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 *.

* Mineral. ii. 499.

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.

† Schrickel.

137 Sulphuret,

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.

138 Phosphurets,

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 ‡.

‡ Ann. de Chim. xiii. 129.

Phosphorus

(Y) The passages in which he mentions it are as follows:—*De Mineral.* lib. ii. cap. 11. "Marchasita, sive 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 toti substantiæ 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 fixionem approximantis, et sulphuris adurentis. Ipsam habere sulphureitatem comperimus manifesta experientia. Nam cum sublimatur, ex illa emanat substantia sulphurea manifesta comburens. Et sine sublimatione similiter perpenditur illius sulphureitas.

"Nam si ponatur ad ignitionem, non suscipit illam priusquam inflammatione sulphuris inflammetur, et ardeat. Ipsam vero argenti vivi substantiam manifestatur habere sensibiliter. 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 Alchimiæ, illam has substantias continere in radice sua."

(Z) The real discoverer of this method appears to have been Dr Isaac Lawson. See *Pott*, III. Diss. 7. and *Watson's Chemical Essays*.

(A) Pott observed, that it was $\frac{1}{18}$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, εριων τολυπαις αφομοιουνται, v. 85. p. 352.

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 blowpipe, 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.

140 Alloys,

Zinc combines with moſt of the metals:

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.
‡ Keir'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.

‖ Elemens 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 to 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*.

* Mem. Par. 1742.

7. Tin and zinc combine eaſily. The alloy is harder than tin. This alloy is often the principal ingredient in the compound called *pewter*.

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†.

† Ann. de Chim. ix. 95.

141 And affinities.

The affinities of zinc, according to Bergman, are as follows:

Copper,
Antimony,
Tin,
Mercury,
Silver,
Gold,
Cobalt,
Arſenic,
Platinum,
Biſmuth,
Lead,
Nickel,
Iron.

SECT. X. *Of Antimony.*

Antimony.

THE ancients were acquainted with an oxide of antimony to which they gave the names of στιμμι 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 τετραγωνον 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.

(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 ære 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. It has a sensible taste, but no smell *.

* Fourcroy.

143 Properties of antimony.

It is neither malleable nor ductile, but exceedingly brittle. Its specific gravity, according to Brisson, 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.

† Kirwan's Miner. ii. 244.

‡ Bergman.

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.

§ Kirwan's Miner. ii. 489.

‖ Ibid.

¶ Rouelle.

The affinities of the grey oxide of antimony are, according to Bergman, as follows:

Sebacic acid,
Muriatic,
Benzoic (D)?
Oxalic,
Sulphuric,
Pyromucous *,
Nitric,
Tartarous,
Saccholactic,
Phosphoric,
Citric,
Succinic,
Fluoric,
Arsenic,
Formic,
Lactic,
Acetous,
Boracic,
Prussic,
Carbonic.

* Schrickel.

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 *.

* Bergman, iii. 167.

The grey oxide of antimony is also capable of combining with about $\frac{4}{100}$ of sulphur. This compound, by fusion, may be converted into glass. It was formerly used in medicine under the name of *glass of antimony*.

146 Phosphuret,

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 facettes. 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 †.

† Pelletier, Ann. de Chim. xiii. 132.

Antimony is capable of combining with most of the metals

147 Alloys,

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.

‡ Dr Lewis.

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 §.

§ Gellert.

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 ‖.

‖ Id.

7. The alloy of tin and antimony is white and brittle; its specific gravity is less than intermediate ¶.

¶ Id.

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.

* Gmelin, Ann. de Chim. viii. 319.

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.

† Gellert.

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?

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.

It is brittle. Its hardness is 6 *. Its specific gravity is 9,8227 †. It melts at 460° Fahrenheit ‡. When heated in close vessels, it sublimes. When allowed to cool slowly after fusion, it crystallizes.

* *Kirwan.* † *Brisson.* ‡ *Lewis.*

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,
Saccholactic,
Succinic,
Citric,
Formic,
Lactic,
Acetous,
Prussic,
Carbonic,
Ammonia.

Sulphur combines readily with bismuth by fusion. 150 Sulphuret, 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 *.

* *Wenzel, Kirwan's Miner.* ii. 492.

There appears to be little affinity between bismuth and phosphorus. Mr Pelletier attempted to produce the phosphuret of bismuth by various methods without success. 151 Phosphuret, 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 †.

† *Ann. de Chim.* xiii. 130.

Bismuth combines readily with most of the metals. 152 Alloys,

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 *pewter.* 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.

‡ *Keir, Macquer's Dict.* § *Ibid.* ‖ *Dr Lewis.* ¶ *Cramer.* * *Chim. Dijon,* i. 3. † *Dr Lewis.*

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°.

153 And affinities. The affinities of bismuth, according to Bergman, are as follows:

Lead,
Silver,
Gold,
Mercury,

(E) Muriatic acid decomposes benzoat of bismuth.—*Trommsdorf, Ann. de Chim.* xi. 317.

Mercury,
Antimony,
Tin,
Copper,
Platinum,
Nickel,
Iron,
Sulphuret of alkali,
Sulphur,
Phosphorus ?

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 σανδαραχη (F), and his disciple Theophrastus αρρενικον, 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 *.

* *Bergman*, ii. 278.

153 Properties of arsenic.

Arsenic, when pure, is of a bluish white colour. It is exceedingly brittle. Its hardness is 7 †. Its specific gravity 8,310 ‡.

† *Kirwan's Miner.* ii. 254.
‡ *Bergman*, ii. 278.

When exposed to the temperature of 354° in close vessels it sublimes §, and crystallizes in regular tetrahedrons.

§ *Ibid.*

It is not much altered by water. Boiling water, however, is capable of dissolving, and retaining $\frac{1}{10000}$th of arsenic; but that part of the metal is no doubt reduced to the state of an oxide ||.

154 Its oxides,

|| *Habneman, Chim. Ann.* 1788, i. 182.

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 ¶.

¶ *Kirwan's Miner.* ii. 490.

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 alliacious 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:

* *Bergman*, ii. 278.
† *Brandt, Act. Upsal*, 1733.
‡ *Bergman*, ii. 278.

Muriatic acid,
Oxalic,
Sulphuric,
Nitric,
Sebacic,
Tartarous,
Phosphoric,
Fluoric,
Saccholactic,
Succinic,
Citric,
Formic,
Lactic,
Arsenic,
Acetous,
Prussic,
Ammonia,
Water,
Alcohol ?

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 *.

* *Berthollet, Kirwan's Miner.* ii. 490.

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*.

155 Sulphuret,

† *Kirwan's Miner.* ii. 492.
‡ *Ibid.*

156 Phosphuret,

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 §.

§ *Pelletier, Ann. de Chim.* xiii. 139.

Arsenic unites with most metals, and in general renders them more brittle and more fusible.

1. Melted gold takes up $\frac{1}{60}$th of arsenic ||. The alloy is brittle and pale.

|| *Bergman, ibid.*

2. Melted silver takes up $\frac{1}{14}$th of arsenic ¶. The alloy is brittle.

¶ *Ibid.*

157 Alloys,

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 *.

* *Ibid.*

5. Copper takes up $\frac{5}{6}$ths of arsenic †. This alloy is white;

† *Ibid.*

(F) Pliny seems to make a distinction between sandaracha and arsenic. See Lib. xxxiv. c. 18.

Cobalt. white; and when the quantity of arsenic contained in it is small, both ductile and malleable *. It is called *white tombac*.

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 ‡.

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.

8. Lead takes up $\frac{1}{6}$th of arsenic §. The alloy is brittle and dark coloured.

9. Zinc takes up $\frac{1}{5}$th of arsenic, antimony $\frac{1}{8}$th, and bismuth $\frac{1}{15}$th ‖.

158 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.

* Gellert.

† Bergman, Ann de Chim xiii. 139.

‡ Kirwan's Miner. ii. 256.

§ Bergman, Ibid.

‖ Ibid.

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* ¶.

159 Properties 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 as cast iron, which melts at 130° Wedgewood. No heat has been produced great enough to volatalize it ‡.

Cobalt, when pure, does not seem to be affected by air or water.

It is attracted by the magnet.

¶ Act. Upsal. 1733.

* Leonhardi.

† Kirwan's Miner. ii. 268.

‡ Bergman, iv.

160 Its oxides.

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,
Saccholactic,
Succinic,
Citric,
Formic,
Lactic,
Acetous,
Arsenic,
Boracic,
Prussic,
Carbonic,
Ammonia.

* Kirwan's Miner. ii. 268. 490.

161 Sulphuret,

The *sulphuret of cobalt* is not formed without difficulty. It is scarcely known.

162 Phosphuret,

Phosphuret of cobalt may be formed by heating the metal red hot, and then gradually dropping in small bits of phosphorus. It contains about $\frac{1}{15}$th 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 †.

163 Alloys,

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-

† Pelletier, Ann. de Chim. xiii. 134.

‡ Bergman's Elect. Attract.

§ Metallur. Chim.

(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.

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.*

12. Arsenic combines very readily with cobalt. The alloy is brittle, much more fusible, and more easily oxidated than pure cobalt †.

† *Bergman*, iv.

164
And affinities.

The affinities of cobalt are as follows:

Iron,
Nickel,
Arsenic,
Copper,
Gold,
Platinum,
Tin,
Antimony,
Zinc,
Sulphuret of alkali,
Sulphur,
Posphorus?

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 be beg 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.

166
Its properties,

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 ‡.

* *Kirwan's Miner.* ii. 281.
† *Bergman*, ii. 231.
‡ *Ibid.*

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 §.

§ *Ann. de Chim.* i. 170.

167
Oxides,

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:

¶ *Kirwan's Miner.* ii. 490.

Oxalic acid,
Muriatic,
Sulphuric,
Tartarous,
Nitric,
Sebacic,
Phosphoric,
Fluoric,
Saccholactic,
Succinic,
Citric,
Formic,
Lactic,
Acetous,
Arsenic,
Boracic,
Prussic,
Carbonic,
Ammonia,
Potass?
Soda?

168
Sulphuret,

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.

169
Phosphuret,

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.

* *Pelletier, Ann. de Chim.* xiii. 135.

170
Alloys,

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.

† *Bergman*, ii. 231.

171
And affinities.

Its affinities, according to Bergman, are as follows:

Iron,
Cobalt,
Arsenic,

Copper,

Manganese.

Copper,
Gold,
Tin,
Antimony,
Platinum,
Bismuth,
Lead,
Silver,
Zinc,
Sulphuret of alkali,
Sulphur,
Popsphorus ?

Sect. XV. *Of Manganese.*

[171] Discovery of manganese.

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 *terræ magnesiæ*. 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 scoriæ, 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 properties,

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.

† *Kirwan's Miner.* ii. 288.

‡ *Hielm.*

When reduced to powder, it is attracted by the magnet.

173 Oxides,

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 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,
Saccholactic,
Succinic,
Sebacic,
Tartaric,
Formic,
Lactic,
Acetous,
Prussic,
Carbonic.

The sulphuret of manganese is unknown.

174 Phosphuret,

Phosphorus may be combined with manganese by 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 *.

* *Pelletier, Ann. de Chim.* xiii. 137.

175 Carburet,

Manganese combines readily with carbon by fusion (1).

176 Alloys,

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.

† *Ann. de Chim.* i. 303.

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 ‡.

‡ *Bergman*, ii. 211.

177 And affinities.

The affinities of manganese, according to Bergman, are as follows:

Copper,
Iron,
Gold,

Silver,

(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.

Tungſten.

Silver,
Tin,
Sulphuret of alkali,
Phoſphorus ?
Carbon ?

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 $\frac{65}{100}$ 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.

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 *Encyclopædia*; to which, therefore, we beg leave to refer.

* Luyart. † Id. ‡ Id. § Id. || Pelletier, Ann. de Chim. xiii. 137.

Sect. XVII. *Of Molybdenum.*

180 Diſcovery of molybdenum.

The Greek word *molybdena*, 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 *molybdena*.

Molybdenum.

Molydbena 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 molybdena*. 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. Klaproth and Pelletier alſo attempted to reduce it, and with equal ſucceſs. The metal is *molybdenum* (K).

181 Its properties.

Molybdenum is externally of a whitiſh yellow colour, but its fracture is a whitiſh grey.

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*.

Molybdenum combines readily with ſulphur; and the compound has exactly the properties of molybdena, the ſubſtance which Scheele decompounded ‡. Molybdena is therefore *ſulphuret of molybdenum*. The reaſon that Scheele obtained from it molybdic acid was, that the metal combined with oxygen during his proceſs.

Molybdenum is alſo capable of combining with phoſphorus §.

Few of the alloys of this metal have been hitherto examined.

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 *.

* Pelletier, Journ. de Phyſ. 1785. † Ibid. ‡ Ibid. § Pelletier, Ann. de Chim. xiii. 137. || Ruprecht, Ann. de Chim. viii. 8. ¶ Hielm, Ann. de Chim. iv. 17. * Pelletier, Journal de Phyſique, Dec. 1785.

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

(K) This name was given it by Hielm.

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, Crell's Journal, Eng. Transl. i. 126.

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).

† Ibid.

183 Its properties. Uranium is of a dark grey colour; internally it is somewhat inclined to brown ‡.

‡ Ibid. 233.

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 shorl*; 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 potass, and heated in a porcelain furnace, it melted, and formed when cold 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 *.

* M'Gregor.

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. 186 Menachanite.

† Mineral. ii. 331.

Sect. XX. *Of Tellurium.*

In the mountains of Fatzbay, near Zalethna in Transylvania, there is a mine called *Mariahilf*; 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). 187 Discovery of tellurium.

Tellurium is of a white colour like tin, approaching somewhat to the grey colour of lead ‡. 188 Its properties.

‡ Klaproth, Philosophical Magazine, i. 78.

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 §.

§ Muller.

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 ‖.

‖ Klaproth.

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 formed

(L) *Blende* is the name given to ores of zinc.

(M) From *Uranus* (Ουρανος), 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.*

189 Chromum.

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.

190 General table of the properties of the metals.

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.		299¼	
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.		29¼	
Zinc.	White.	6	7,190	700 F.		o	
Antimony.	Grey.	6½	6,860	700 F.	o	o	
Bismuth.	Yellow-white.	6	9,822	460 F.	o	o	
Arsenic.	White.	7	8,310	400 F. ?	o	o	
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.	o	o	Magnetic.
Tungsten.	Brown.	6	17,600		o	o	
Molybdenum	Grey.		7,500		o	o	
Uranium.	Grey.	6	6,440				
Titanium.	Red.	9	4,180		o	o	
Tellurium.	White.		6,115	540 F.	o	o	
Chromum.	Grey.				o	o	

(o) From χρωμα, because it possesses the property of giving colour to other bodies in a remarkable degree.

(P) W. Wedgewood's pyrometer. F. Fahrenheit's thermometer.

We

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?

* *Ann. de Chim.* xxiii. 85.—*Nicholson's Journ.* i. 453.

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 $\frac{27}{100}$ and $\frac{48}{100}$, and consequently of forming 20 or 30 different oxides; it can only combine with precisely $\frac{27}{100}$ parts, or $\frac{48}{100}$ 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 $\frac{27}{100}$ of oxygen; if it be oxidated more than this, it must be combined with $\frac{48}{100}$ 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 metals, 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.

Tellurium.

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 commmon properties.

(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*.

Every body which possesses the following properties is an *earth*:

192 Properties of earths.

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, jargonia, 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 gravity is 2,3 *.

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 of 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 ‡.

195 Lime-water.

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.

* *Kirwan's Miner.* i. 5.

† *Journ. de Phys.* t. 22

‡ *Dr Black.*

§ *Kirwan's Miner.* i. 5.

One thousand parts of lime are capable of absorbing, and retaining, at a heat of 600°, 228 parts of water *.

* *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.

196 Sulphuret, and

Lime unites readily with sulphur, and forms *sulphuret 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 sulphuret 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.

197 Phosphuret of lime.

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.

198 Cause of the difference between limestone and lime.

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.

199 According to Stahl;

200 Explained by Dr Black.

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;

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 decompounded; and limestone is composed of carbonic acid and lime. Heat separates the carbonic acid, and leaves the lime in a state of purity.

201 Affinities of lime.

The affinities of lime, according to Bergman, are as follows:

Oxalic acid,
Suberic (R)?
Sulphuric,
Tartarous,
Succinic,
Phosphoric,
Saccholactic,
Nitric,
Muriatic,
Sebacic,
Fluoric,
Arsenic,
Formic,
Lactic,
Citric,
Benzoic,
Sulphurous,
Acetous,
Boracic,
Nitrous,
Carbonic,
Prussic,
Sulphur,
Phosphorus,
Water,
Fixed oil.

Sect. II. *Of Magnesia.*

202 Discovery 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 potass 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.

Magnesia.

* Bergman, i. 365.

203 Method of procuring it.

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 potass added. The magnesia is immediately precipitated, because potass has a stronger affinity for sulphuric acid. It is then to be washed with a sufficient quantity of water, and dried.

204 Its properties.

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° ‡.

† Kirwan's Miner. i. 8.

‡ Ibid.

Even when combined with carbonic acid (for which it has a strong affinity) it is capable of absorbing and retaining $1\frac{1}{4}$ 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.

Effect of heat on mixtures of lime and magnesia.

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° Wedgewood. 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.

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,
Saccholactic,
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 *βαρυς, heavy*), which Bergman changed into *barytes;* and this last term is now universally adopted.

Barytes. 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:

208 Method of obtaining it. Reduce the mineral to a powder and mix it with $2\frac{1}{2}$ its weight of carbonat of soda (T), 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 (U) 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 ‡.

* *Afsvelius, Ann. de Chim.* iii.
† *Hope, Edin. Trans.* iv. 36.
‡ *Fourcroy* and *Vauquelin, Ann. de Chim.* xxi. 276.

209 Its properties. 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 ‖.

§ *Edin. Trans. ibid.*
‖ *Ann. de Chim. ibid.* and *Nicholson's Journal*, i. 535.

Cold water dissolves about $\frac{1}{17}$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 foliacious appearance, not unlike the leaf of a fern ¶.

¶ *Hope, ibid.*

These crystals are transparent and colourless, and appear to be composed of about 53 parts of water and 47 of

(T) 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; potass might also be used.

(U) Except strontites, which Pelletier has detected in this mineral.

Barytes. of barytes. When expofed to the heat of boiling water, they undergo the *watery fufion*, or, which is the fame thing, they melt without lofing any of the water which they contain. A ftronger heat makes the water fly off. When expofed to the air, they attract carbonic acid, and crumble into duft. They are foluble in $17\frac{1}{2}$ parts of water at the temperature of 60°; but boiling water diffolves any quantity whatever: the reafon of which is evident; at that temperature their own water of cryftallization is fufficient to keep them in folution *.

* *Id.*

Water faturated with barytes is called *barytic water*. It has the property of converting vegetable blues to a green.

When barytes is expofed to the blowpipe on a piece of charcoal, it fufes, bubbles up, and runs into globules, which quickly penetrate the charcoal †. This is probably in confequence of containing water; for Lavoifier found barytes not affected by the ftrongeft heat which he could produce.

† *Fourcroy* and *Vauquelin, ibid.*

210
Sulphuret of barytes.

Barytes combines readily with fulphur. The eafieft way of forming fulphuret of barytes is to mix eight parts of fulphat of barytes with one part of pounded charcoal, and to apply a ftrong heat. The charcoal combines with the oxygen of the fulphuric acid, and the compound flies off in the form of carbonic acid gas. There remains behind fulphur combined with barytes. Sulphuret of barytes is foluble in water: It is of a yellow colour. It is capable of cryftallizing; and then affumes a yellowifh white colour ‡.

‡ *Fourcroy.*

The phofphuret of barytes has not been examined.

No mixture of barytes and lime, nor of barytes and magnefia, is fufible in the ftrongeft heat which it has been poffible to apply §.

§ *Lavoifier, Acad. Par.* 1782.

211
Its affinities.

The affinities of barytes, according to Bergman, are as follows:

Sulphuric acid,
Oxalic,
Succinic,
Fluoric,
Phofphoric,
Saccholactic,
Suberic (v)?
Nitric,
Muriatic,
Sebacic,
Citric,
Tartarous,
Arfenic,
Fluoric,
Lactic,
Benzoic,
Acetous,
Boracic,
Sulphurous,
Nitrous,
Carbonic,
Pruffic,
Sulphur,
Phofphorus,
Water,
Fixed oils.

Sect. IV. *Of Strontites.*

Strontites.

212
Difcovery of ftrontites.

About the year 1787, a mineral was brought to Edinburgh, by a dealer in foffils, from the lead mine of Strontian in Argylefhire, where it is found imbedded in the ore, mixed with feveral other fubftances. It is fometimes tranfparent and colourlefs, but generally has a tinge of yellow or green. Its hardnefs is 5. Its fpecific gravity varies from 3,4 to 3,726. Its texture is generally fibrous; and fometimes it is found cryftallized in flender prifmatic columns of various lengths *.

* *Hope, Edin. Tranf.* iv. 44.

This mineral was generally confidered as a carbonat of barytes; but Dr Crawford having obferved fome differences between its folution in muriatic acid and that of barytes, mentioned in his treatife on *Muriat of Barytes*, publifhed in 1790, that it probably contains a new earth, and fent a fpecimen to Mr Kirwan that he might examine its properties. Dr Hope had alfo fufpected that its bafis differed from barytes; and accordingly he made a fet of experiments on it in 1791, which were read to the Royal Society of Edinburgh in 1792. Thefe experiments fully proved that it contained a peculiar earth. Mr Kirwan likewife analyfed the ftrontian mineral, and drew precifely the fame conclufions. It has been analyfed alfo by Mr Klaproth of Berlin, and Mr Pelletier of Paris. It confifts of carbonic acid combined with a peculiar earth, to which Dr Hope gave the name of *ftrontites*. This appellation we fhall adopt.

The carbonic acid may be feparated by a heat of 140° Wedgewood, and then the ftrontites remains behind †.

† *Kirwan's Miner.* i. 332.

Strontites has been found in Argylefhire in Scotland, near Briftol in England, and in Pennfylvania ‡. It has been found alfo in France and in Sicily. It is of a white colour. It has a pungent acrid tafte. When pounded in a mortar, the powder that rifes is offenfive to the noftrils and lungs §. It is not poifonous ‖.

‡ *Klaproth,* ii. fect. 39.

213
Its properties.

§ *Hope, ibid.*
‖ *Pelletier.*

One hundred and fixty-two parts of water, at the temperature of 60°, diffolve nearly one part of it. The folution is clear and tranfparent, and converts vegetable blues to a green. Hot water diffolves it in much larger quantities; and as it cools the ftrontites is depofited in colourlefs tranfparent cryftals. Thefe are in the form of thin quadrangular plates, generally parallelograms, the largeft of which feldom exceeds one-fourth of an inch in length. Sometimes their edges are plain, but they oftener confift of two facets, meeting together and forming an angle like the roof of a houfe. Thefe cryftals generally adhere to each other in fuch a manner as to form a thin plate of an inch or more in length and half an inch in breadth. Sometimes they affume a cubic form. They contain about 68 parts in 100 of water. They are foluble in 51,4 parts of water, at the temperature of 60°. Boiling water diffolves nearly half its weight of them. When expofed to the air, they lofe their water, attract carbonic acid, and fall into powder ¶.

¶ *Hope, ibid.*

When ftrontites is thrown into water, it attracts it with a hiffing noife, much heat is produced, and it falls into powder much more rapidly than lime *.

* *Id.*

It combines with fulphur either by fufion in a crucible, or by being boiled with it in water. The fulphuret

(v) Suberic acid decompofes muriat and nitrat of barytes. *Jamefon'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 ſtrontites, 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 potaſs, 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.

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.

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 §.

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 ‖.

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 Miner.* i. 10.
‡ *Ibid.*
§ *Ibid.*
‖ *Scheele.*
¶ *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 *.

* *Bergman*, 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 potaſs and carbonat of potaſs (w). The cruſt on the top conſiſted partly of carbonat of potaſs, 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 †.

† *Nicholſon's Jour.* i. 217.

Silica endures the moſt violent heat without alteration.

It ſeems incapable of combining with ſulphur or phoſphorus.

217 Effect of heat on mixtures of lime and ſilica;

1. The effect of heat upon lime and ſilica, mixed in various proportions, will appear from the following experiments of Mr Kirwan ‡.

‡ *Mineral.* i. 56.

Proportions.	Heat.	Effect.
50 Lime 50 Silica	150° Wedg.	Melted into a maſs of a white colour, ſemitranſparent at the edges, and ſtriking fire, tho' 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.

218 Magneſia and ſilica:

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 ‖.

§ *Lavoiſier, Mem. Par.* 1787, p. 598.

219 Barytes and ſilica;

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) Potaſs, combined with ſulphuric acid and with carbonic acid.

Silica.

Proportions.	Heat.	Effect.
80 Silica 20 Barytes	155° Wedg.	A white brittle mass.
75 Silica 20 Barytes	150	A brittle hard mass, semi-transparent at the edges.
66 Silica 33 Barytes	150	Melted into a hard somewhat porous porcelain mass.
50 Silica 50 Barytes	148	A hard mass 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 mass.
33 Silica 66 Barytes	150	Melted into a yellowish and partly greenish white porous porcelain.

4. The effect of heat on mixtures of strontites and silica is not known.

220 And lime, magnesia, and silica.

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 *.

* *Mem. Berl. ibid.* and *Jour. de Phys.* xxiv.

221 Affinities of silica.

The affinities of silica are as follows:

Fluoric acid,
Fixed alkali.

Sect. VI. *Of Alumina.*

222 Method of obtaining alumina.

Dissolve alum in hot water, and add to the solution potass 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.

223 Its properties.

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.

† *Kirwan's Miner.* i. 9

Alumina.

With a small quantity of water it forms a very tough ductile paste, and does not readily mix with more.

In its usual state of dryness it is capable of absorbing $2\frac{1}{2}$ 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 †.

† *Shaw's Boyle*, iii. 422.

224 Wedgewood's thermometer.

Wedgewood 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.*

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 ‡.

‡ *Nicholson's Jour.* ii. 101.

225 Effect of heat on mixtures of lime and alumina;

1. The effect of heat on various mixtures of lime and alumina will appear from the following table §:

§ *Kirwan*, i. 56.

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.

226 Magnesia and alumina;

2. Magnesia and alumina have no action whatever on each other, even when exposed to a heat of 150° Wedgewood ‖.

‖ *Ibid.* i. 57.

227 Barytes and alumina;

3. The effect of heat on different mixtures of barytes and alumina will appear from the following experiments of Mr Kirwarn ¶.

¶ *Ibid.*

Kk 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.

Alumina.

Proportions.	Heat.	Effect.
80 Alumina 20 Barytes	150° Wedg.	Scarcely hardened.
75 Alumina 25 Barytes	156	No fign of fufion, a loofe 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 fign of fufion.
25 Alumina 75 Barytes	150	Harder, but no fign of fufion.

4. Nothing is known concerning the effect of heat on mixtures of ftrontites and alumina.

228 Alumina and filica;

5. Equal parts of alumina and filica harden in the temperature of 160° Wedgewood, but do not fufe *. Achard found them infufible in all proportions in a heat probably little inferior to 150° Wedgewood. Mixtures of thefe two earths in various proportions form *clays*, but thefe are feldom uncontaminated with fome other ingredients.

* Kirwan's Min. i. 58.

229 Lime, magnefia, and alumina;

6. From the experiments of Achard, it appears that no mixture of lime, magnefia, and alumina, in which the lime predominates, is vitrifiable, except they be nearly in the proportions of three lime, two magnefia, one alumina; that no mixture in which magnefia predominates will melt in a heat below 166°; that mixtures in which the alumina exceeds are generally fufible, as will appear from the following table †.

† Ibid. i. 72.

3 Alumina 2 Lime 1 Magnefia	A porcelain.
3 Alumina 1 Lime 2 Magnefia	A porcelain.
3 Alumina 1 Lime 3 Magnefia	Porous porcelain.
3 Alumina 2 Lime 3 Magnefia	Porous porcelain.
3 Alumina 2 Lime 2 Magnefia	Porcelain.

230 Lime, filica, and alumina;

7. From the fame experiments, and thofe of Kirwan, we learn, that in mixtures of lime, filica, and alumina, when the lime exceeds, the mixture is generally fufible either into a glafs or a porcelain, according to the proportions. The only infufible proportions were,

2	3	Lime
1	1	Silica
2	2	Alumina.

That if the filica exceeds, the mixture is frequently fufible into an enamel or porcelain, and perhaps a glafs; and that when the alumina exceeds, a porcelain may often be attained, but not a glafs *.

* Ibid. i. 73.

231 Magnefia, filica, and alumina;

8. As to the mixtures of magnefia, filica, and alumina, when the magnefia exceeds, no fufion takes place at 150°. When the filica exceeds, a porcelain may often be attained; and three parts filica, two magnefia, and one alumina, formed a glafs. When the alumina exceeds, nothing more than a porcelain can be produced †.

† Ibid. i. 71.

232 And lime, magnefia, filica, and alumina.

9. Achard found that equal parts of lime, magnefia, filica, and alumina, melted into a glafs. They fufed alfo in various other proportions, efpecially when the filica predominated.

233 Affinities of alumina.

The affinities of alumina as as follows:

Sulphuric acid,
Nitric,
Muriatic,
Oxalic,
Arfenic,
Fluoric,
Sebacic,
Tartarous,
Succinic,
Saccholactic,
Citric,
Phofphoric,
Formic,
Lactic,
Benzoic,
Acetous,
Boracic,
Sulphurous,
Nitrous,
Carbonic,
Pruffic.

Sect. VII. *Of Jargonia.*

234 Difcovery of jargonia.

Among the precious ftones which come from the ifland of Ceylon, there is one called *jargon*, which is poffeffed of the following properties.

Its colour is various, grey, greenifh white, yellowifh, reddifh brown, and violet. It is often cryftallized, either in right angular quadrangular prifms furmounted with pyramids, or octahedrals confifting of double quadrangular pyramids. It has generally a good deal of luftre, at leaft internally. It is moftly femitranfparent. Its hardnefs is from 10 to 16: Its fpecific gravity from 4,416 to 4,7 ‡.

‡ Ibid. i. 333.

It lofes fcarcely any of its weight in a melting heat; 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 firft §. Neither was it attacked either by muriatic or fulphuric acid, even when affifted by heat. At laft, by calcining it with a large quantity of foda, he diffolved it in muriatic acid, and found that 100 parts of it contained 31,5 of filica, five of a mixture of nickel,

§ Jour. de Phyf. 36. 180.

Glucina.

el and iron, and 68 of an earth possessed of peculiar properties. This earth has been called *jargonia*.

235 Its properties.

Jargonia 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 potass or soda, and in being infusible by heat when mixed with these substances in a state of dryness *.

No more of its properties are yet known.

* *Kirwan's Mineral.* 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 potass. 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 potass; the precipitate is to be washed, and then dissolved in sulphuric acid. When the solution, after potass 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 hydrosulphuret, similar in its properties to other hydrosulphurets. Glucina is soluble in the liquid fixed alkalies; 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 alkalies; 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 austerity.

Yttria and Agustina.

239 Discovery of agustina.

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.

240 Remarks on the earths.

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 decompounded, 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 (Y). 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 *austrum*; a third from lime, also called *austrum*; and a fourth from alumina, which they denominated *apulum*. 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.

* *Chemistry,* p. 217. Eng. Transl.

But their experiments were soon after repeated by Klaproth, Savoresi, and Tihauski; and these accurate chemists

(Y) Mr Sage, however, pitched upon lime.

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 propertis.

* See *Pictet sur le Feu*, ch. 1.

242 Caloric expands bodies.

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:

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.*

Table

Table of the Expansion of various Bodies at different Temperatures continued.

* Kirwan.
† De Luc.

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 Vernois, Encyc. Method. art. Air.

Table of the Expansion of Metals from 32° to 212° †.

† Smeaton, Phil. Trans. xlviii. 612.

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	120204	120225	120232
White heat		123428*	121500*	122571*				

* Rinman.

	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

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.

243 Exception.

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 equably, 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 coloric, 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. Tranſ.* 1786, Part I.

247 The particles of caloric repel each other.

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 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

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(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 Boſcovich, 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 $2150\frac{1}{16}$ 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 $\frac{1}{16}$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 $\frac{3}{16}$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 $\frac{3}{16}$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 $\frac{1}{1000}$ 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 Chaussier 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.

248 Bodies become lighter by being heated,

249 And why.

* Phil. Transf. 1785, Part II.

† Journ. de Phys. 1785, Oct.

‡ Journ. de Savans, 1785, p. 493.

250 Caloric moves more readily upwards than downwards

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 higher than 95°; but the thermometer A reached 101,75°. 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° 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° in 34 minutes, which was 93″ sooner than the inferior B: it rose to 110,75°, the thermometer B only to 106,25°. The tube being reversed, the thermometer A, which was now lowest, rose from 46° to 115,25° 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°, remained stationary for 80″, and after five minutes had only descended 0,45°: the other did not ascend at all; in one minute it descended 0,225°, and in 6′ 8″ it descended 2,47°. In 22′ 50″ the inferior descended 63,725°, the superior 61,475° *. 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.

§ See Manometer in this Suppl.

* Pictet sur le Feu, chap. 2.

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.*

251 Conducting power of bodies:

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

252 Of wood and charcoal;

(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 $\frac{1}{20}$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 *.

* Rumford's Eſſays, ii. 229.

253 Of glaſs; 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.

254 Of metals; Metals are the beſt conductors of caloric of all the ſolids hitherto examined. The conducting powers of all, however, are not equal. Dr Ingenhouſz 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,
Gold,
Copper, } nearly equal.
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, potaſs 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.

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 192 258 Proofs of the non-conducting power of water,

(F) When tranſparent, it tranſmits caloric.

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192 gr. of eiderdown mixed with it, which would merely tend to embarrafs the motion of the particles. A quantity of ftewed apples were alfo in another experiment put into the cylinder. The following Tables exhibit the refult of all thefe experiments.

Time the Caloric was in paffing into the Thermometer.

Temperature.	Through the Water and Starch.	Thro' the Water and Eiderdown.	Through ftewed Apples.	Through pure Water.
	Seconds.	Seconds.	Seconds.	Seconds.
Therm. rofe from 32° to 200° in	1109	949	1096½	597
Therm. rofe 80°, *viz.* from 80° to 160°, in	341	269	335	172

Time the Caloric was in paffing out of the Thermometer.

Temperature.	Through the Water and Starch.	Thro' the Water and Eiderdown.	Through ftewed Apples.	Through pure Water.
	Seconds.	Seconds.	Seconds.	Seconds.
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 ftarch nor the eiderdown could produce any alteration in the water except impeding its internal motions; confequently whatever impedes thefe motions diminifhes the conducting power of water. But this could not happen unlefs every individual particle actually went from the cylinder to the thermometer. Hence it follows that, if liquids be conductors, their conducting power is but fmall when compared with their carrying power.

259 Shewn to be inconclufive.

All liquids, however, are capable of conducting caloric; for when the fource of heat is applied to their furface, the caloric gradually makes its way downwards, and the temperature of every ftratum gradually diminifhes from the furface to the bottom of the liquid. The increafe of temperature in this cafe 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 conclufion from his experiments. He fixed a cake of ice in the bottom of a glafs jar, covered one-fourth inch thick with cold water. Over this was poured gently a confiderable quantity of boiling water. Now if water were a non-conductor, no caloric could pafs through the cold water, and confequently 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 firft fight, a decifive proof that water is a conductor. But the Count has fallen upon a very ingenious method of accounting for the melting of the ice, without being under the neceffity (as he tells us) of renouncing his theory that fluids are non-conductors.

It is well known that the fpecific gravity of water at 40° is a maximum: if it be either heated above 40°, or cooled down below 40°, its denfity diminifhes. Therefore, whenever a particle of water arrives at the temperature of 40°, it will fink to the bottom of the veffel. 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 fink, difplace the water at 32°, come into contact with the ice, and of courfe melt it. The Count's ingenuity, never without refources, 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 flips of wood, that part which was fhaded 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 thefe facts it certainly may be concluded that the ice was melted by defcending currents of water.

But the point to be afcertained, is not whether there were defcending 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 furface; for the Count himfelf tells us, that there the temperature was never under 108°: not by the fides of the veffel; for the defcending current in one experiment was exactly in the axis: and it follows irrefiftibly, from the experiment with the flips of wood, that thefe defcending currents fell equally upon every part of the furface of the ice; which would have been impoffible if thefe currents had been cooled by the fide of the veffel. The hot water, then, muft have been cooled down to 40° by the cold water below it; confequently it muft have imparted caloric to this cold water. If fo, one particle of water is capable of abforbing caloric from another; that is, *water is a conductor of caloric.* After the hot water has ftood an hour over the ice, its temperature was as follows:

At the furface 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 poffible to account for this gradual diminution of heat as we approach the ice, if water be a non-conductor? The water, it may be faid, gives out caloric at its furface, falls down, and arranges itfelf according to its fpecific gravity. If fo, 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, inftead of demonftrating that water is a non-conductor, rather favours the common opinion that it is a conductor.

260 Mercury and oil proved to be conductors.

The Count tried whether oil and mercury be conductors in the following manner: When water was frozen in a glafs jar by means of a freezing mixture, Count Rumford obferved that the ice firft began to be formed at the fides, and gradually increafed in thicknefs; and that the water on the axis of the veffel, which retained its fluidity longeft, being compreffed by the expanfion of the ice, was forced upwards, and when completely frozen,

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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 $\frac{2}{10}$ths of an inch. The end of the sheath descended $\frac{1}{10}$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.

261 Transmission of caloric radiant 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*.

262 Specific caloric of bodies, what.

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 become colder and the alcohol hotter: 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

(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.

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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.

263 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 tinplate, filled with boiling water, and kept there till it acquired a certain temperature, which was ascertained by a thermometer. Into another small box of tinplate 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 gravities. 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 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 $= \frac{32g+c}{g+1}$. 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°.	Temper. 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 $\frac{N-32}{c-N}=\frac{1}{\frac{c-N}{N-32}}$, 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 $\frac{1}{\frac{c-N}{N-32}}$
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 needlefs to add, that the laft column marks the denominator of the fpecific caloric of the metal, the numerator being always 1, and the fpecific caloric of water being 1. Thus the fpecific caloric of gold is $\frac{1}{19{,}712}$. In exactly the fame manner, and by taking a mean of a number of experiments at different temperatures, did Mr Wilcke afcertain the fpecific caloric of a number of other bodies. He afcertained at the fame time, that the fpecific caloric of a body did not vary with the temperature, but continued always the fame. 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 enfure accuracy, were the experiments of Dr Crawford, made by mixing together bodies of different temperatures. Thefe were publifhed in his *Treatife on Heat*.

265 Lavoifier and La Place, Several experiments on the fpecific caloric of bodies were made alfo by Lavoifier and De la Place, which, from the well-known accuracy of thefe philofophers, cannot but be very valuable.

Their method was exceedingly fimple and ingenious; it was firft fuggefted by De la Place. An inftrument was contrived, to which Lavoifier gave the name of *calorimeter*. It confifts of three circular veffels nearly infcribed into each other, fo as to form three different apartments, one within the other. Thefe three we fhall call the *interior*, *middle*, and *external cavities*. The interior cavity *ffff* (fee fection of the inftrument fig. 4.), into which the fubftances fubmitted to experiment are put, is compofed of a grating or cage of iron wire, fupported by feveral iron bars. Its opening or mouth LM is covered by the lid HG, which is compofed of the fame materials. The middle cavity *bbbb* is filled with ice. This ice is fupported by the grate *mm*, and under the grate is placed a fieve. The external cavity *aaaa* is alfo filled with ice. We have mentioned already, that no caloric can pafs 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 meafure 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 fubftance, the fpecific caloric of which is to be afcertained, is heated a certain number of degrees, fuppofe to 212°, and then put into the interior cavity enclofed in a thin veffel. As it cools, it melts the ice in the middle cavity. In proportion as it melts, the water runs through the grate and fieve, and falls through the conical funnel *ccd* and the tube *xy* into a veffel 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 firft cafe, the ice in the middle cavity might be cooled too low; in the laft, a current of air flows through the machine and carries off fome of the caloric. By putting various fubftances at the fame temperature into this machine, and obferving how much ice each of them melted in cooling down to 32°, it was eafy to afcertain the fpecific caloric of each. Thus, if water, in cooling from 212 to 32, melted one pound of ice, and mercury ,029 of a pound; the fpecific caloric of water was one, and that of mercury ,029. This appears by far the fimpleft method of making experiments on this fubject; and muft alfo be the moft accurate, provided we can be certain that all the melted fnow 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, fo far from flowing out, actually *froze* again, and choaked up the paffage.

A table of the fpecific caloric of various bodies was likewife drawn up by Mr Kirwan, and publifhed by Magellan in his Treatife on Heat. 266 And Kirwan.

From all thefe fources we have drawn up the following table, which exhibits at one view the fpecific caloric of thofe bodies on which experiments have hitherto been made. 267 Refult of thefe experiments.

We have added to it a column, expreffing the fpecific caloric of equal bulks of the fame bodies; which feems to be a more accurate way of confidering this fubject, and indeed the only way in which the phrafe *capacity for caloric* is intelligible. This column was formed by multiplying the fpecific caloric of equal weights of the various fubftances into their refpective fpecific gravities.

Table

TABLE of the Specific Caloric of Various Bodies, that of Water being = 1,0000 (H).

Bodies.	Specific Gravity.	Specific Caloric of equal Weight.	Specific Caloric of equal Volumes.
I. GASES*.			
Hydrogen gas - -	0,000094	21,4000	0,00214
Oxygen gas - - -	0,0034	4,7490	0,006411
Common air - - -	0,00122	1,7900	0,002183
Carbonic acid gas -	0,00183	1,0459	0,001930
Steam - - - - -		1,5500	
Azotic gas - - -	0,00120	0,7036	0,000952
II. LIQUIDS.			
Water - - - - -	1,0000	1,0000	1,0000
Carbonat of ammonia †		1,851	
Arterial blood* - -		1,030	
Cows milk* - - -	1,0324	0,9999	1,0322
Sulphuret of ammonia†	0,818	0,9940	0,8130
Venous blood* - -		0,8928	
Solution of brown ſugar†		0,8600	
Nitric acid‡ - - -		0,844	
Sulphat of magneſia 1, Water 8 †		0,844	
Common ſalt 1, Water 8 †		0,832	
Nitre 1, Water 8 ‡ - - -		0,8167	
Muriat of ammonia 1, Water 1,5 †		0,779	
Tartar 1, Water 237,3 † -		0,765	
Solution of potaſs † -	1,346	0,759	1,2216
Sulphat of iron 1, Water 2,5 †		0,734	
Sulphat of ſoda 1, Water 2,9 †		0,728	
Oil of olives † - -	0,9153	0,710	0,6498
Ammonia† - - -	0,997	0,7080	0,7041
Muriatic acid† - -	1,122	0,6800	0,763
Sulphuric acid 4, Water 5 ‡		0,6631	
Alum 1, Water 4,45 † - -		0,649	
Nitric acid 9⅓, Lime 1 ‡ -		0,6181	
Nitre 1, Water 3 † - - -		0,646	
Alcohol * - - -	0,8371	0,6021	0,4993
Sulphuric acid § - -	1,840	0,5968	1,120
Nitrous acid† - -	1,355	0,576	0,780
Linſeed oil† - - -	0,9403	0,528	0,4964
Spermaceti oil * - -		0,5000	
Oil of turpentine † -	0,9910	0,472	0,4132
Vinegar† - - - -		0,3870	0,3966
Lime 9, Water 16 ‡ - -		0,3346	
Mercury ¶ - - -	13,568	0,3100	4,123
Diſtilled vinegar † -		0,1030	0,1039

Bodies.	Specific Gravity.	Specific Caloric of equal Weight.	Specific Caloric of equal Volumes.
III. SOLIDS.			
Ice † - - - - - -		0,9000	
Ox-hide with the hair *		0,787	
Lungs of a ſheep * -		0,769	
Lean of ox-beef * -		0,7400	
Rice * - - - - - -		0,5050	
Horſe beans * - -		0,5020	
Duſt of the pine tree *		0,5000	
Peaſe * - - - - -		0,4920	
Wheat * - - - -		0,4770	
Barley * - - - -		0,4210	
Oats * - - - - - -		0,4160	
Pitcoal * - - - -		0,2777	
Charcoal * - - - -		0,2631	
Chalk * - - - -		0,2564	
Ruſt of iron * - -		0,2500	
White oxide of antimony waſhed * - - -		0,2270	
Oxide of copper nearly freed from air * -		0,2272	
Quicklime (*c*) - -		0,2199	
Stoneware † - - -		0,195	
Agate ** - - - -	2,648	0,195	0,517
Cryſtal ‡ - - - -	3,189 ?	0,1929	0,6151
Cinders * - - - -		0,1923	
Swediſh glaſs ** - -	2,386	0,187	0,448
Aſhes of cinders * -		0,1885	
Sulphur † - - - -	1,99	0,183	0,3680
Flint glaſs † - - -	3,3293	0,174	0,5792
Ruſt of iron nearly freed from air * - - -		0,1666	
White oxide of antimony ditto * - - -		0,1666	
Aſhes of the elm * -		0,1402	
Oxide of zinc nearly free from air * - - -		0,1369	
Iron (*d*) - - - -	7,876	0,1264	0,993
Braſs (*d*) - - - -	8,358	0,1141	0,971
Copper (*d*) - - -	8,784	0,1121	1,027
Sheet iron ‡ - - -		0,1099	
Oxide of lead and tin *		0,102	
Gun-metal ‖ - - -		0,1100	
White oxide of tin nearly free from air * -		0,0990	
Zinc (*d*) - - - -	7,154	0,0981	0,735
Aſhes of charcoal* -		0,0909	
Silver ** - - - -	10,001	0,082	0,833
Yellow oxide of lead nearly freed from air *		0,0680	
Tin (*e*) - - - - -	7,380	0,0661	0,444
Antimony (*d*) - -	6,107	0,0637	0,390
Gold ** - - - -	19,040	0,050	0,966
Lead (*e*) - - - -	11,456	0,0424	0,487
Biſmuth ** - - -	9,861	0,043	0,427

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.

268 Latent caloric, 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.

269 Caloric of fluidity.

* *Sur le Feu*, ch. I.

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.

† *Jour. de Phys.* xxvi.

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 convered 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 140°; 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°.

270 Caloric of evaporation.

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.

* *Ann de Chim.* xi. 27.

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 (K). 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

272 Irvine's theorem to discover it.

(K) 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 exstinguimur. Quod quidem Cleanthes his etiam argumentis docet, quanta vis insit caloris in omni corpore: negat enim ullum esse cibum tam gravem, quin is nocte et die concoquatur; cujus etiam in reliquiis inest calor his quas natura respuerit. Jam verò venæ et arteriæ micare non desinunt, quasi quodam igneo motu; animadversumque sæpe est, cùm cor animantis alicujus evolsum 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 faciliùs cernemus, toto genere hoc igneo, quod tranat omnia, subtiliùs explicato. Omnes igitur partes mundi (tangam autem maxumas) calore fultæ sustinentur. Quod primùm in terrena natura perspici potest. Nam et lapidum conflictu atque tritu elici ignem videmus; et recenti fossione

—— *terram fumare calentem;*

atque etiam ex puteis jugibus aquam calidam trahi, et id maxumè fieri temporibus hibernis, quòd magna vis caloris, terræ contineatur cavernis; eaque hieme fit densior; ob eamque caussam, calorem insitum in terris contineat arctiùs.

"Longa est oratio, multæque rationes, quibus doceri possit, omnia, quæ terra concipiat, semina, quæque ipsa ex se generata stirpibus infixa contineat, ea temperatione caloris et oriri et augescere. Atque aquæ etiam admixtum esse calorem, primùm ipse liquor, tum aquæ declarat effusio: quæ neque conglaciaret frigoribus, neque nive pruinaque concresceret, nisi eadem se admixto calore liquefacta et dilapsa diffunderet. Itaque et aquilonibus reliquisque frigoribus durescit humor: et idem vicissim mollitur tepefactus et tabescit calore. Atque etiam maria agitata ventis ita tepescunt, ut intellegi facilè 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, cùm 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 effervescunt 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, cùm omnes mundi partes sustineantur calore, mundum etiam ipsum simili parique natura in tanta diuturnitate servari: eoque magis, quòd intellegi debet, calidum illud atque igneum ita in omni fusum esse natura, ut in eo insit procreandi vis et caussa gignendi, à quo et animantia omnia, et ea quorum stirpes terra continentur, et nasci sit necesse et augescere. *Cicero de natura Deorum*, lib. ii. c. 9 *et* 10.

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.

273 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 La Place 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 $9\frac{1}{3}$ 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 to 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.

274 And found inſufficient.

Dr Irvine's theorem, therefore, is inſufficient for aſcertaining the real zero; and hitherto no method has been diſcovered which can ſolve this problem.

275 Caloric exiſts in bodies

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

* See *Seguin, Ann. de Chim.* vii.

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?

276 **In a state of chemical combination.**

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.

278 **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 subtile 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 12250°. 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.

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.

279 **And to be the cause of their gaseous form.**

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.

280 **Why caloric appears during combustion,**

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.

281 **And during many chemical combinations.**

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.

282 **Why certain mixtures produce cold.**

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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them had while feparate. Thus, filver has no perceptible affinity for fulphuric acid, neither has oxygen; but unite them together, and they combine with that acid very readily. A great many inftances of the fame kind might be produced. Were there fubftances, then, which, after combining together, have a greater affinity for caloric than any of them had while feparate, this ought not to furprife us, becaufe the fame phenomenon is often obferved in other bodies. Now this is actually the cafe with regard to caloric. Mix together, for inftance, common falt and fnow, the mixture inftantly becomes liquid, and fo cold, that it finks the thermometer down to zero. In this cafe, the fnow and falt united have a much ftronger affinity for caloric than either of them had while feparate; they attract it therefore from other bodies with which they happen to be in contact, till they have obtained a dofe fufficient for their faturation; and this faturation they manifeft by becoming liquid. It is for this reafon that all falts produce cold during their folution in water, when the freezing point of the folution formed is below that of water. All fuch folutions have a ftrong affinity for caloric; they therefore attract it till they are faturated, which appears by their becoming fluid. A number of experiments have been lately made in order to procure artificial cold by means of fuch combinations. The moft complete fet of experiments of that nature with which we are acquainted, is thofe of Mr Walker, publifhed in the Philofophical Tranfactions for 1795. We fhall prefent the refult of his experiments in the following Table:

TABLE of Freezing Mixtures.

Mixtures.		Thermometer finks.
Muriat of ammonia Nitre - - Water - -	5 parts. 5 16	From 50° to 10°.
Muriat of ammonia Nitre - - Sulphat of foda Water - -	5 5 8 16	From 50 to 4.
Nitrat of ammonia Water - -	1 1	From 50 to 4.
Nitrat of ammonia Carbonat of foda Water - -	1 1 1	From 50 to 7.
Sulphat of foda Diluted nitric acid	3 2	From 50 to 3.
Sulphat of foda Muriat of ammonia Nitre - - Diluted nitric acid	6 4 2 4	From 50 to 10.
Sulphat of foda Nitrat of ammonia Diluted nitric acid	6 5 4	From 50 to 14.
Phofphat of foda Diluted nitric acid	9 4	From 50 to 12.
Phofphat of foda Nitrat of ammonia Diluted nitric acid	9 parts. 6 4	From 50° to 21°.
Sulphat of foda Muriatic acid -	8 5	From 50 to 0.
Sulphat of foda Diluted fulphuric acid	5 4	From 50 to 3.
Snow - - Common falt -	1 1	From 32 to 0.
Snow or pounded ice Common falt -	2 1	From 0 to —5.
Snow or pounded ice Common falt - Muriat of ammonia and Nitre - -	1 5 5	From —5 to —18.
Snow or pounded ice Common falt - Nitrat of ammonia	12 5 5	From —18 to —25.
Snow and diluted nitric acid		From 0 to —46.
Snow - - Diluted fulphuric acid Diluted nitric acid	2 1 1	From —10 to —56.
Snow - - Diluted fulphuric acid	1 1	From 20 to —60.

In order to produce thefe effects, the falts employed muft be frefh cryftallized, and newly reduced to a very fine powder. The veffels in which the freezing mixture is made fhould be very thin, and juft large enough to hold it, and the materials fhould be mixed together as quickly as poffible. The materials to be employed in order to produce great cold ought to be firft reduced to the temperature marked in the table, by placing them in fome of the other freezing mixtures; and then they are to be mixed together in a fimilar freezing mixture. If, for inftance, we wifh to produce a cold = —46, the fnow and diluted nitric acid ought to be cooled down to 0, by putting the veffel which contains each of them into the 12th freezing mixture in the above table, before they are mixed together. If a ftill greater cold is required, the materials to produce it are to be brought to the proper temperature by being previoufly placed in the fecond freezing mixture. This procefs is to be continued till the required degree of cold has been procured *.

* *Walker, Phil. Tranf.* 1795.

283 Subftances which contain moft caloric.

11. From the facts already known, we may conclude, that the particles of caloric have two properties, that of repelling each other, and of attracting and being attracted by other fubftances. As there is no body in nature which does not contain caloric, we may fafely conclude, that there is no body in nature which has not an affinity for it. When it unites with bodies, though the repulfion of its particles may be overcome by their attraction for the particles of the body, and by the attraction

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 indefinitely 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.

286 Cauſe of the different conducting powers of different bodies.

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.

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.

287 How heat paſſes thro' ſolids.

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

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.

288 Bodies cool each other reciprocally.

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.

289 And why.

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.

290 Cause of the difference in the specific caloric of bodies.

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

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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.*

291 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.

294 Whether it ever takes place when oxygen is not present.

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.

295 Stahl's theory of combustion by the extrication of phlogiston.

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.

296 Improved by Macquer,

Macquer, to whose illustrious labours several of the most important branches of chemistry owe their existence, was, we believe, the first person who perceived a 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 distin-

(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 annimal could breathe it without suffocation (K). 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 recurred with double force, What is phlogiston? Dr

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 an-

299 Kirwan's theory of phlogiston swered. 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.

* In his *Treatise on Phlogiston.*

300 Refuted.

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. 302 Production of caloric by percussion,

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 303 Owing partly to condensation,

† *T. Wedgewood, Phil. Transf.* 1792.

(K) 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 brittler 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.

* Darwin, *Phil. Transf.* 1788.

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.

305 Sparks emitted by quartz stones on elision.

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. 306 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.

* Lamanon, *Journ. de Phys.* 1785.

306 Cause of this unknown.

† *Ann. de Chim.* xvi. 206.

307 Emission of caloric on friction.

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

308 Not owing to condensation,

(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 Maouna. 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.

309 Nor to decrease of specific caloric,

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.

* Nicholson's Journ. ii. 106.

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 $7\frac{3}{4}$ inches in diameter and $9\frac{8}{10}$ inches long. It remained joined to the rest of the metal by a small cylindrical neck. In this cylinder a hole was bored 3,7 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 $\frac{1}{948}$ 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 †.

† Ibid.

310 Nor to combustion;

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 Pictet 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 adamantine 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°, 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°. When a bit of wood was made to rub against the brass cup in the air, the thermometer rose 0,7°, and on substituting also a wooden cup it rose 2,1°, and in the exhausted receiver 2,4°, and in air condensed to $1\frac{1}{4}$ atmospheres it rose 0,5° *.

* *Pictet 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 *.

* *Nicholson, ibid.*

311 And consequently at present inexplicable.

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.

312 This no proof that caloric is not a body.

313 Analogy between caloric and electricity.

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.

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°. It rose to 70,2° in 732″. The same experiment was repeated, but no electric matter thrown in; the thermometer rose from 49,8° to 70,2° in 1050″; so that the electricity hastened the heating almost a third. In the first experiment the thermometer rose only to 71,3°, 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° to 74,7° 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 †.

* *Pictet sur le Feu.* ch. 6.

† *Ibid.* ch. 9.

314 Electricity may be an agent in the heating of bodies by friction.

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 substance, 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?

Light.

CHAP. VI. *Of* LIGHT.

315 Newtonian theory 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 subtile 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.

316 Velocity of light.

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.

317 Divisible into seven rays.

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.

318 Differing in refrangibility.

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 *.

* *Edinburgh Phil. Trans.* iii.

When light passes within a certain distance of a body, parallel

(o) Dr Franklin did the same, without taking any notice of these philosophers, of whose opinions perhaps he was ignorant. See *Trans. Philad.* III. 5.

Light.

parallel to which it is moving, it is bent *towards* it; when it passes at a greater distance, it is bent *from* it.

319 Inflection, deflection,

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 reflexity.

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 reflexity, 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 capable of entering bodies,

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 bason 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 bason 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 Grosser 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.

* *Jour. de Phys.* xx. 270.

322 And of being combined with them.

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.

† *Priestley and Ingenhousz.*

‡ *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.

* Berthollet.

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.

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.

325 Light heats bodies.

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 throw 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 Wedgewood 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 thermometer

* Phil. Trans. 1792.

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 *. 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.

* Phil. Tranſ. 1780.

† Sur le Feu, ch. 4.

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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 hed 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. Wedgewood, 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.

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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. Wedgewood 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.

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Inquiry into the cauſe of theſe phenomena.

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.

* T. Wedgewood, 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.

but different substances (R). How then does caloric occasion the appearance of light, and light that of caloric?

329 Supposed owing to the mutual repulsion of light and 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 *.

The same ingenious gentleman has observed, that gold, silver, copper, and iron, become luminous when heated in times inversely proportional to their specific calorics †. Now the specific calorics of these metals are in the following order:

Iron,
Copper,
Silver,
Gold.

They

* *Phil. Trans.* 1792, p. 1.

† *Ibid.*

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° to 14°; in another, from 4,2° to 14,3°. 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°; and when the glass was again removed it rose in seven minutes to 11,1°; 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 matrass 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 $50\frac{1}{8}$; and the moment the matrass 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 $51\frac{1}{8}$ to $55\frac{1}{4}$.

The mirrors of tin were now placed at the distance of 90 inches from each other; the matrass 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 $\frac{1}{18}$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 matrass. When the polished side of this mirror was turned to the matrass, the thermometer rose only 0,5°; but when the side covered with tinfoil, and which had been blackened with ink and smoke, was turned toward the matrass, the thermometer rose 3,5°. In another experiment, when the polished side of the mirror was turned to the matrass the thermometer rose 3°, when the other side 9,2°. 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 matrass 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 matrass 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 expofed to the fame degree of heat, in the following order:

Gold,
Silver,
Copper,
Iron.

Now the fmaller the fpecific caloric of any body is, the lefs muft be the quantity of caloric neceffary to raife it a given number of degrees; the fooner therefore muft it arrive at the temperature at which it gives out light. It was natural to expect, then, if the emiffion of light from a body by the application of heat be owing to the repulfion between caloric and light, that thofe bodies fhould become luminous fooneft in which that repulfion increafes with the greateft rapidity; and this we fee is precifely the cafe. The only queftion to be determined before drawing this conclufion is, Whether the fame 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 fee, then, that this conducting power is nearly in the order in which thefe metals become luminous; fo that the greateft quantity of caloric would enter thofe which become fooneft luminous. Now this is juft what ought to happen, provided the expulfion of light from a luminous body, by the application of heat, be owing to the repulfion between the particles of caloric and light.

The repulfion between the different rays of light and caloric does not feem to be equal; the repulfion between the blue rays and caloric feems to be greater than that between the red rays and caloric; and the repulfion between all the rays and caloric feems to be directly as their refrangibility: accordingly, when heat is applied to a body, the blue rays efcape fooner, and at a lower temperature, than the red rays and others which are moft refrangible. When fulphur, for inftance, is burnt at a low temperature, the colour of the flame is blue; and when examined by the prifm, it is found to confift of the violet, indigo, blue, and fometimes of a fmall quantity of the green rays*; but when this fubftance is burnt at a high temperature, the colour of the flame is white, all the rays feparating together. When bodies have continued to burn for fome time, they may be fuppofed to have loft the greater part of the moft refrangible rays; hence the red appearance of bodies, charcoal for inftance, that have burnt for fome time, the only rays which remain to feparate being the orange, yellow, and red†.

* *Morgan, Phil. Tranf.* 1785.

† *Ibid.*

The blue rays feem not only to repel caloric with greater force, but likewife to have a greater affinity for other bodies than the red rays have; for they decompofe the oxide of filver (or rather the muriat of filver) much fooner, and to a greater extent, than the red rays‡: hence we fee the reafon why the application of the blue rays to Mr Wilfon's pyrophori and to the diamond caufes an extrication of red rays.

‡ *Sennebier.*

We have feen already, that the gafes are not heated red hot by the application of heat. It would follow from this, that the gafes do not contain light: but the contrary is certain; for light is actually extricated during the combuftion of hydrogen, and muft therefore have exifted either in the oxygen or hydrogen gas, or in both. Probably therefore the reafon that heat does not extricate light from the gafes is, that the affinity between their bafes and light is exceedingly ftrong: it would therefore require a more than ufual temperature to produce its extrication; and on account of the great dilatability of thefe gafes, which always tends to diminifh the repulfion between the caloric and light, this temperature cannot be applied. It is eafy to fee, upon the fuppofition that there exifts a repulfion between caloric and light, why the accumulation of light fhould produce heat, and why light only occafions heat in thofe bodies that abforb it.

Such is the theory of the caufe of the reciprocal extrication of light and caloric by the application of thefe fubftances refpectively to bodies, which has been propofed by feveral ingenious chemifts (s); and we acknowledge frankly, that it appears to us by far the moft plaufible of all the explanations of this phenomenon with which we are acquainted.

330 Objections to which this theory is liable.

It is not, however, beyond the reach of objections, and objections too, we are afraid, altogether incompatible with its truth. Were the repulfion between caloric and light the only caufe of the luminoufnefs of hot bodies, the continual application of heat would furely in time feparate the whole of the light which was combined with the body, and then it would ceafe to be luminous altogether; but we have no reafon to fuppofe that bodies ever ceafe to become luminous by the continued application of heat. Claveus kept melted, and confequently red hot, gold for months in a furnace; but he does not fay that its luminoufnefs was diminifhed, far lefs deftroyed; and had fuch a remarkable phenomenon taken place, certainly he would not have failed to inform us; but fo far from that, he exprefsly fays that it fuffered no alteration (T) §.

§ *Shaw's Boyle*, iii. 268.

Whether light would continue to extricate a great deal of caloric during fo long a time, has never been tried: but we have no reafon for fuppofing that its power to produce that effect is ever exhaufted; for bodies, after being expofed to the fun for years, and even for ages, are juft as much heated by it as ever. But thefe effects, far from being inexhauftible, ought, according to the theory, to come very fpeedily to an end. It is certainly probable, then, as other philofophers have fuppofed, that though light and caloric are not precifely one and the fame fubftance, they are fome how or other intimately connected, and are either compofed of different proportions of the fame ingredients, or the one enters into the compofition of the other.

One

(s) Particularly by Dr Parr, who is faid to be the author of a paper on this fubject, publifhed in the *Exeter Memoirs*.

(T) A gentleman, to whom we mentioned this objection, obferved, that in the cafe of bodies long expofed to heat, the light which appears to proceed from them, might, in fact, be extricated from the atmofphere by the caloric communicated to it from the heated body. This thought is new and ingenious, and might eafily be put to the teft of experiment. Some of the facts mentioned in the text are rather hoftile to it; but fhould it prove well founded, it would go far to remove moft of the difficulties in which the theory of light is at prefent involved.

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 (T). 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 (U). 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 Meteorologie.*

Mr de Luc, so well known for his important meteorolgical 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 expansive 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.

Another theory has been advanced by the late Dr Hutton of Edinburgh (V); 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. 333 Hutton's theory.

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

(T) 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.*

(U) 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.

(V) See his dissertations on different subjects of natural philosophy.

(W) Indeed Dr Hutton refused this property to gravitating matter also; following, in this particular, the theory of the celebrated Boscovich.

(X) 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.), 998,74 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

338 Impregnated with various salts. mixture of various salts with water affect 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 *:

* *Trans. 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 potass		0,9
	Nitrat of potass		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 potass,	Small quantity of, lowers do.	0,45
	Saturated solution of, raises do.	11,2

Water was once supposed to be incompressible, but 339 Water compressible. the contrary has been demonstrated by Mr Canton. The Abbé Mongez made a number of experiments, long after that philosopher, on the same subject, and obtained similar results.

Water was believed by the ancients to be one of the 340 Opinion about its nature. 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 Waselton, 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.

* *Shaw's Boyle*, iii. 417.

† *Ibid.* i. 267.

We have formerly mentioned, that water is composed of oxygen and hydrogen. This great discovery has con-

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 *.

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 †.

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 sooty substance ‡, which Dr Priestley afterwards supposed to be a part of the mercury used in filling the vessel §.

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 $2\frac{1}{2}$ 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.

* Macquer's *Dictionary*, art. *Gas, inflammable*.

† *Mem. Par.* 1781, 470.

‡ *Priestley*, v. 395.

§ *Phil. Trans.* lxxiv. 332.

‖ *Ibid.* lxxv. 330.

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 ‡.

* *Mem. Par.* 1781, p. 470.

† *Ibid.* p. 472.

‡ *Ibid.* p. 474.

342 Proofs of the composition of water.

The proofs that water is a compound are of two kinds; it has been actually composed, and it has been decomposed.

343 Experiment of Lavoisier and Meusnier.

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 potass, 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 potass, 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 (y). The whole machine is described at large by Mr Meusnier in the Memoirs of the Academy of Sciences for 1782.

(y) A variety of instruments have been invented by the French chemists for that purpose. These instruments they have denominated *Gazometers*.

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 potass, 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 potass. 1152 grains of that water being saturated with potass, 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.

344 Experiment 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 Phys. 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 $\frac{1}{674}$ 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 potass, and furnished by evaporation 26,5 grains of crystals of nitre. The whole water, therefore, would have required 109,7 grains of carbonat of potass 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 eight of their weight. It contained 462 grains of carbonic acid gas, or about $\frac{1}{6}$th part; the rest was azotic gas, with about $\frac{1}{11}$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.

345 Experiment of Seguin, Fourcroy, and Vauquelin.

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 atmospherical 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 potass (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 $\frac{3}{100}$ 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 potass.

Water.

The combustion continued 185 hours; and during all that time our philosophers 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 1,000053 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
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
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.

	Gr Troy
The quantity of azotic gas introduced was	151,178
The quantity found in the residuum was	170,258
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.

Water.

Hydrogen that disappeared, -	852,690 gr. troy.
Oxygen, - - - - - - - -	5093,940
Total, - -	5946,630
Quantity of water obtained,	5943,798
Which is less than the gases consumed by - - - - -	2,832 grains *.

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:

* Ann. de Chim. viii. 225.

346 Objections to the composition of water examined.

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 $\frac{1}{12}$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 $\frac{1}{6}$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 $\frac{1}{8}$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 $\frac{1}{331}$ 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

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 $\frac{1}{25}$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 $\frac{1}{18}$th and $\frac{1}{40}$th of its weight when washed in *milk of lime* (B).

* *Ann. de Chim.* iii. 91.

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 $\frac{1}{131}$ 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 $\frac{1}{100}$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 $\frac{1}{217}$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.

† *Ann. de Chim.* ix. 48.

‡ *Phil. Transf.* 1784.

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 *.

* *Keir's Dictionary*, art. *Nitrous Acid.*

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 $\frac{1}{20}$th of the oxygen gas employed. Mr Berthollet, however, has shewn that it could not have amounted to more than $\frac{1}{44}$th part ‡. Let us suppose, however, that it amounted to $\frac{1}{20}$th. A 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 $\frac{1}{20}$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 $\frac{19}{20}$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

† *Phil. Transf.* 1788.

‡ *Ann de Chim.* iii. 86.

(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.*

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).

* Ann. de Chim. iii. 94.

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 5946 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.

347 Decomposition of water.

But the experiments above related, conclusive as they appear, are not the only ones by which this important fact has been ascertained. Messrs Van Trooftwyk and Dieman, assisted by Mr Cuthbertson, filled a small glass tube, $\frac{1}{8}$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 atmospherical 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 atmospherical 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 *.

* Jour. de Phys. xxxv. 369.

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 $\frac{1}{10}$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.

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 liquors 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 *.

‡ Lib. ii. n. 77.

§ *De Morib. Germ.* ch. xxiii.

* *Berg.* 4th. art. ii. 4.

350 Method of procuring it.

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 potaſs 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. Potaſs in this ſtate has a ſtrong attraction for water; it accordingly combines with the water of the ſpirit, and the ſolution of potaſs 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 potaſs 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 potaſs which ought to be uſed, becauſe that muſt depend entirely on the ſtrength of the ſpirit; but it is of no conſequence though the potaſs employed be a little more than enough. The alcohol thus obtained contains a little potaſs diſſolved, which may be ſeparated by diſtilling it in a water bath with a very ſmall heat. The alcohol paſſes over, and leaves the potaſs 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.

351 Its properties.

Alcohol is a tranſparent liquor, colourleſs like water, of a pleaſant ſmell, and a ſtrong penetrating agreeable taſte.

It is exceedingly fluid, and has never been frozen, though it has been expoſed to a cold ſo great that the thermomer 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 $\frac{1}{7}$th part*.

352 Opinions concerning its composition.

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.

* Mem. Par. 1781. p. 493.

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.

† Mem. Par. 1781.

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.

354 Ingredients of alcohol.

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*.

* Nicholson's Journal, i. 391.

When equal parts of sulphuric acid and alcohol are mixed together and heat applied, the mixture boils at 208°, 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 formation. 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 odorant 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 *olefiant 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 :

" 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.

drogen 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 saturated 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.

* *Nicholson's Journ.* i. 391.

358 Substances soluble in alcohol.

Alcohol is capable of dissolving a great many bodies. A considerable number of these, with the quantities soluble, 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		

† *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 ſoda	112
Nitrat of ſilver	100
Refined ſugar	59
Boracic acid	48
Nitrat of ſoda	23
Acetite of copper	18
Muriat of ammonia	17
Arſeniat of potaſs	9
Acidulated oxalat of potaſs	7
Nitrat of potaſs	5
Muriat of potaſs	5
Arſeniat of ſoda	4
Barytes	
Strontites	
White oxide of arſenic	3
Tartrat of potaſs	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 ſoda,
Borax,	magneſia,
Tartar,	Sulphite of ſoda,
Alum,	Tartrite of ſoda and potaſs,
Sulphat of ammonia,	Phoſphoric acid,
lime,	Nitrat of lead,
barytes ‡,	mercury,
iron (green),	Muriat of lead,
copper,	ſilver §,
ſilver,	Common ſalt,
mercury,	Carbonat of potaſs,
zinc,	ſoda.
potaſs,	

‡ *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.

359 Its 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.

* *Gen.* xv. 17.
† *Herodot.* lib. ii. 59. and 62.

Oils are divided into two claſſes, *Fixed* and *Volatile*; each of which is diſtinguiſhed by peculiar properties.

361 Fixed oils. 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.

362 Their properties. 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 $10\frac{1}{4}$ degrees ‡.

‡ *Chaptal's Chemiſtry*, Engliſh Tranſl. iii. 43.

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.

363 Analyſis of olive oil. Mr Lavoiſier analyſed olive oil by burning it in preciſely the ſame apparatus as that which he employed for analyſing alcohol.

The

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 Jour. 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 Sennebier observed, that no such change was produced on the oil though ever so long exposed to the light, provided atmospherical 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.

* 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. 365 Drying oils. *Drying oils*, so called because they are capable of *drying* completely when spread out, a property which renders them useful in painting, seem, as Sennebier 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 †.

† Berthollet.

366 Fixed oils dissolve sulphur,

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.

367 And phosphorus.

Fixed oils dissolve phosphorus. The solution is luminous, from the slow combustion of the 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*.

368 Their affinities.

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.	

369 Volatile oils.

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

(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.

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* (K).

When expoſed to cold, or when kept for a long time, ſome of them depoſite cryſtals reſembling the acid of benzoin (L).

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, *potaſs*, *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 Potaſs.*

372 Method of procuring potaſs.

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 *potaſs*; 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 *potaſh*. 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 potaſs. This is to be diſſolved in water, filtrated, and evaporated to dryneſs. Or potaſs may be obtained by burning tartar wrapt up in brown paper and placed in a crucible (M).

The potaſs 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 potaſs 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 potaſs 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 depoſite 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 Peterſburgh *, potaſs 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

* *Nicholſon*, i. 164.

(K) 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.

(L) See a paper by Margueron on this ſubject, *Ann. de Chim.* xxi. 174.

(M) That potaſs 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 potaſs; not, however, in a ſtate of purity. *Plinii*, lib. xviii. c. 51. The κονια, ιος, 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†.

* Nicholson, 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 subtile 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, astringent, 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.

375 Sulphuret of potash.

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 filtrating 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 Trooftwyck, Nieuwland, and Bondt, ascertained by experiment *. 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.

* Ann. de Chim. xiv. 294.

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.

‖ Ibid. p. 305.

376 Phosphuret of potash.

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.

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 potaſs 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. 32.

377 Glaſs.

When equal parts of ſilica and potaſs are melted together, they combine and form *glaſs*. 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 potaſs is double or triple that of the ſilica, the glaſs is ſoluble in water, and forms what is called *liquor ſilicum*.

Potaſs 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).
Mangaueſe,	Red.
Tungſten,	Colourleſs.
Molybdenum,	Colourleſs.
Uranium,	Grey (opaque).
Titanium,	White (opaque).
Tellurium,	White.
Chromum,	Green.

378 Soap.

Potaſs combines readily with fixed oils, and forms the compound known by the name of *ſoap*.

379 Potaſs, whether a compound.

Potaſs 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 decompounded; and the other two have been detected in the act of formation, though the ingredients which compoſe them have not hitherto been diſcovered.

Whether potaſs 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 improbable. 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 potaſs are as follows: 380 Its affinities

Sulphuric acid,
Nitric,
Muriatic,
Sebacic,
Fluoric,
Phoſphoric,
Oxalic,
Tartarous,
Arſenic,
Succinic,
Citric,
Formic,
Lactic,
Benzoic,
Sulphurous,
Acetous,
Saccholactic,
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 potaſs; 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 potaſs, 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 potaſs in one particular; potaſs attracts moiſture in the air, but ſoda parts with it, and when expoſed to the atmoſphere, ſoon crumbles down into a dry powder. 381 Properties of ſoda.

It is capable of combining with all the ſubſtances with which potaſs unites; but it forms compounds poſſeſſed, in general, of very different properties from thoſe of the compounds into which potaſs enters.

It

(N) If the glaſs be made with ſoda.

(O) But reddiſh if the glaſs be formed of ſoda. *Klaproth.*

(P) The λιτρον of the Athenians was evidently the ſame ſubſtance; and ſo was the נתר of the Hebrews.

Alkalies.

It is reckoned more proper than potaſs for forming glaſs and ſoap.

Some chemiſts have ſuppoſed that it is compoſed of magneſia and azot; but their proofs are inſufficient.

The order of its affinities is the ſame with that of potaſs.

Sect. III. *Of Ammonia.*

382 Diſcovery of ammonia.

Ammonia (q), volatile alkali, or *hartſhorn*, as it is called in commerce, is mentioned as early as the 15th century. Both Baſil Valentine and Raymond Lully deſcribed the methods of procuring it. Dr Black was the firſt who diſtinguiſhed pure ammonia from the carbonat of ammonia, or ammonia combined with carbonic acid; and Dr Prieſtley firſt diſcovered the method of obtaining it in a ſtate of complete purity.

To obtain pure ammonia, mix common ſal ammoniac with three parts of ſlacked lime; apply heat; and receive the product in a veſſel filled with mercury ſtanding in a baſon of mercury. A gas comes over, which is pure ammonia*. This gas is tranſparent like common air, and is not condenſed by cold.

* *Prieſtley on Air*, iii. 371.

383 Its properties.

Its ſpecific gravity is 0,000732. It is to common air as 600 to 1000†.

† *Kirwan on Phlog.* p. 28.

It has a very ſtrong, but not unpleaſant ſmell. Animals cannot breathe it without death. When a lighted candle is let down into this gas, it goes out three or four times ſucceſſively; but at each time the flame is conſiderably enlarged by the addition of another flame of a pale yellow colour, and at laſt this flame deſcends from the top of the veſſel to the bottom‡.

‡ *Prieſtley*, ii. 381.

Water abſorbs this gas with avidity. It diſappears almoſt inſtantly on the introduction of a little water. From an experiment of Dr Prieſtley, it appears that water ſaturated with this gas is of the ſpecific gravity 1,1435§.

§ *Ibid.* p. 372.

This water acquires the ſmell of ammonia. It has a very ſtrong diſagreeable taſte, and converts vegetable colours to a green.

Ammonia in the ſtate of gas has no effect upon ſulphur or phoſphorus. Carbon abſorbs it; probably becauſe it contains water. Neither hydrogen nor azot produce any alteration on it ‖.

‖ *Ibid.* p. 377.

Alcohol and ether abſorb it in conſiderable quantity ¶.

¶ *Ibid.*

384 Its component parts.

Dr Prieſtley diſcovered, that when electric exploſions were made to paſs through this gas, its bulk was gradually augmented to thrice the ſpace which it formerly occupied. It was then moſtly converted into hydrogen gas. He diſcovered, too, that heat produced the very ſame effect*. Theſe experiments prove that hydrogen enters as an ingredient into the compoſition of ammonia.

* *Ibid.* 389.

Mr Scheele obſerved, that when ammonia was treated with the oxides of mangançſe, gold, or mercury, the oxides were reduced; the ammonia diſappeared; and nothing remained but a quantity of azotic gas. Theſe facts induced Bergman to conjecture, that ammonia was compoſed of hydrogen and azot: a conjecture which has been fully confirmed by the experiments of Berthollet.

This ingenious chemiſt obſerved, that if oxy-muriatic acid and ammonia be mixed, an efferveſcence takes place; azot is diſengaged, a quantity of water formed, and the oxy-muriatic acid is converted into common muriatic acid. Now the ſubſtances mixed were ammonia and oxy-muriatic acid, which is compoſed of oxygen and muriatic acid; the products were, muriatic acid, azot, and water, which is compoſed of oxygen and hydrogen. The oxygen of the water was furniſhed by the acid; the other products muſt have been furniſhed by the ammonia, which has diſappeared. Ammonia, therefore, muſt be compoſed of azot and hydrogen. Mr Berthollet proved, that ammonia was compoſed of theſe ingredients by a number of other experiments. For inſtance, if the oxide of copper be heated in contact with ammoniacal gas, it is reſtored to the metallic ſtate; the ammonia diſappears, a quantity of water is formed, and azotic gas is diſengaged. It follows from Mr Berthollet's experiments, that ammonia is compoſed of 121 parts of azot and 29 of hydrogen*. According to Dr Auſtin, it is compoſed of 121 parts of azot, and 32 of hydrogen†.

* *Mem. Par.* 1785.
† *Phil. Tranſ.* 1788.

385 Formation of ammonia.

After the compoſition of ammonia had been thus aſcertained, it became a queſtion of ſome conſequence, Whether it could be formed artificially? Dr Auſtin 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 theſe two ſubſtances were in a gaſeous ſtate, they could not be combined by any method which he could deviſe. It could not be doubted, however, that the combination often takes place when theſe bodies are preſented to each other in a different form. Dr Prieſtley‡ and Mr Kirwan‖ had actually produced it, even before its compoſition was known. Accordingly he found, that when tin is moiſtened with nitric acid, and after being allowed to digeſt for a minute or two, a little potaſs or lime is added, ammonia is immediately exhaled§. In that caſe, the nitric acid and the water which it contains are decompoſed; the oxygen of each unites with the tin, and reduces it to the ſtate of an oxide; and at the ſame time the hydrogen of the water combines with the azot of the acid, and forms ammonia, which is driven off by the ſtronger affinity of the potaſs or lime. Dr Auſtin ſucceeded alſo in forming ammonia by ſeveral other methods. He introduced into a glaſs tube filled with mercury a little azotic gas, and then put into the gas ſome iron filings moiſtened with water. The iron decompoſes the water and combines with its oxygen; and the hydrogen meeting with azot at the moment of its admiſſion, combines with it, and forms ammonia. This experiment ſhews, that the gaſeous ſtate of the azot does not prevent its combination with hydrogen.

‡ *On Air*, ii. 41.
‖ *On Hepatic Air*, § iii.
§ *Dr Auſtin.*

386 Sulphuret of ammonia.

Ammonia may be combined with ſulphur by mixing together two parts of muriat of ammonia (ammonia combined with muriatic acid), two parts of lime, and one part of ſulphur, and diſtilling; a yellow liquor is obtained, which contains ſulphuret of ammonia. It is capable of cryſtallizing.

The phoſphuret of ammonia is unknown.

Ammonia is capable of combining with ſeveral of the metallic oxides, particularly copper.

It combines with fixed oils, and forms *ſoap.*

The order of its affinities is preciſely the ſame with that of the fixed alkalies.

Chap.

(q) We have adopted this word, which is Dr Black's, becauſe we think it preferable to *ammoniac* or *ammoniaca*, the words propoſed and uſed by the French chemiſts.

Chap. V. *Of Acids.*

Substances possessed of the following properties are denominated *acids*.

387 Properties of 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 alkalies, the acids restore them again.

3. They unite with water in almost any proportion.

4. They combine with all the alkalies, 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.

389 Lavoisier's theory.

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 confirmed by every subsequent observation. All the acids hitherto analysed contain oxygen, *one* perhaps excepted, *the Prussic 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).

390 List of the acids.

The acids at present known amount to about 39, most of which have been examined within these 30 years. Their names are as follows:

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. Prussic,
10. Fluoric,	30. Formic,
11. Carbonic,	31. Sebacic,
12. Acetic,	32. Bombic,
13 Acetous,	33. Zoonic,
14. Oxalic,	34. Arsenic,
15. Tartarous,	35. Tungstic,
16. Citric,	36. Molybdic,
17. Malic,	37. Chromic,
18. Lactic,	38. Platinic,
19. Saccholactic,	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.

ſulphur, and the air of the atmoſphere furniſhes the reſt. The acid thus obtained is not quite pure, containing a little potaſs, 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 ſulphuric acid itſelf may be diſtilled over pure.

393 Its component parts.

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 potaſs †. 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.

* Mem. Par. 1781, 232.

† Mem. Par. 1782, 603.

394 Its properties.

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°.

395 Its cryſtals.

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 *.

‡ Encyc. Method. Chim. i. 376.

§ Journ. de Phyſ. xxxi. 473.

396 Its affinity for water.

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.

* Phil. Tranſ. lxxvii. Part ii.

† Phil. Tranſ. 1684.

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 1,969lbs. 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.

‡ Mem. Par. 1780.

397 Strength of ſulphuric acid of various denſities.

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.

§ Iriſh Tranſ. iv.

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 $\frac{1}{11}$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 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

Sulphuric Acid.

different quantities of ſtandard acid and water, was as in the following table :

Number of parts 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 $n\,\mathrm{B} = \overline{n - x} \times \mathrm{A}$. Therefore $x = \frac{\mathrm{A} - \mathrm{B}}{\mathrm{A}} \times n$, or (making $n = 1$) $= \frac{\mathrm{A} - \mathrm{B}}{\mathrm{A}}$. $\frac{\mathrm{A} - \mathrm{B}}{\mathrm{A}}$ 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 c, calling the number of meaſures n, the number of meaſures of alcohol x, the increaſe of denſity

Sulphuric Acid.

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 standard acid	100 parts, at the specific gravity	Contain of standard acid	100 parts, at the specific gravity	Contain of standard 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.

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 potass, 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?

398 Quantity of real acid in strong sulphuric 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 potass. Their respective experiments give the following numbers:

	Homb.	Berg.	Wenzel.	Wiegleb.
100 parts of potass require	38,3	78,5	82,63	101,92.

Homberg used carbonat of potass, 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 potass 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; and Mr Kirwan, with his usual candour, has accordingly abandoned it, and adopted another method which is not liable to the same exceptions. He dissolved 1523,5 grains

* *Encyc. Method.* art. *Affinité.*

† *Keir's Dictionary*, art. *Acid.*

density or diminution of bulk z; we shall have $c : z :: \frac{n}{2} \times \frac{n}{2} : \overline{n - x}, \times x$ and $z = \frac{4c}{n^2} \times \overline{nx - x^2}$, 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.

grains of pure carbonat of potafs, dried in a red heat, in diftilled water. The whole weighed 4570 grains. He took 360 grains of this mixture, which contained 120 grains of carbonat of potafs, and faturated it with pure fulphuric acid of the fpecific gravity 1,565, which, according to the above table, contained 61 *per cent.* of ftandard acid. The acid required for faturating the folution of potafs amounted to 130 grains, and contained therefore 79 of ftandard. The carbonic acid difengaged was 34 grains, and confequently the quantity of alkali was 120 — 34 = 86 grains. The folution being turbid, was diluted with 3238 grains of water. Its fpecific gravity was then 1,013 at the temperature of 60°. The weight of the whole was 3694 grains. Forty-five grains of fulphat of potafs (potafs combined with fulphuric acid), diffolved in 1017 grains of diftilled water, have the fame fpecific gravity at the fame temperature; from whence it follows, that the proportion of falt in each was equal. But in the laft folution the quantity of falt was $\frac{1}{23,6}$ of the whole; therefore the quantity of falt in the firft 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, muft be acid. But the quantity of ftandard acid employed was 79 grains; of this there were $8\frac{1}{2}$ grains which did not enter into the combination, and which muft have been pure water: 79 parts of ftandard acid, therefore, contain at leaft 8,5 parts of water, and confequently 100 parts of ftandard acid contain 10,75 parts of water. It only remains now to confider how much water fulphat of potafs contains. Mr Kirwan thinks it contains none, becaufe it lofes no weight in any degree of heat below ignition, and even when expofed to a red heat for half an hour it hardly lofes a grain. This is certainly fufficient to prove, at leaft, that it contains very little water; and confequently we may conclude, with Mr Kirwan, that 100 parts of fulphuric acid, of the fpecific gravity 2,000, are compofed pretty nearly of 89,25 of pure acid and 10,75 of water. This method ufed by Mr Kirwan is nearly the fame with that propofed by Mr Keir *.

* *Keir's Dictionary,* art. *Acid.*

It feems even poffible to obtain fulphuric acid free from all the water that may not be neceffary to its acid ftate. When it is procured by diftillation from green vitriol, if the receiver be changed after the procefs has gone on for fome time, a quantity of acid is obtained in a folid form, or cryftallized. This, as Morveau has fhewn, is fulphuric acid deprived of the water with which it is ufually combined. When this *glacial* acid, as it has been called, is expofed to the air, it rifes in white fumes, and is foon diffipated. This fingular effect is produced by its violent attraction for the water which exifts in atmofpheric air. When thrown into water, it feizes it with violence; a great deal of caloric is evolved, fufficient, if the quantity of water be not too great, to elevate the whole in vapours *.

* *Encyc. Method. Chim.* i. 590.

399 Action of this acid on other bodies.

Sulphuric acid is capable of decompofing alcohol and oils; and when affifted by heat, it decompofes alfo fome of the metallic oxides which contain the greateft quantity of oxygen; as red oxide of lead, black oxide of manganefe. It decompofes likewife all the fulphurets and phofphurets which have an alkaline or earthy bafis.

It oxidates iron, zinc, and manganefe, in the cold. By the affiftance of heat it oxidates filver, mercury, copper, antimony, bifmuth, arfenic, tin, and tellurium. At a boiling heat it oxidates lead, cobalt, nickel, molybdenum. It does not act upon gold, platinum, tungften, nor titanium.

It unites readily with all the alkalies, the alkaline earths, alumina, and jargonia, and with moft of the metallic oxides, and forms falts denominated *fulphats*. Thus the combination of fulphuric acid and foda is called *fulphat of foda*; the compound of fulphuric acid and lime, *fulphat of lime*, and fo on. It does not act upon filica nor adamanta.

400 Its affinities.

The affinities of fulphuric acid are as follows †:

Barytes,
Strontites ‡,
Potafs,
Soda,
Lime,
Magnefia,
Ammonia,
Alumina,
Jargonia § ?
Oxide of zinc,
—— iron,
—— manganefe,
—— cobalt,
—— nickel,
—— lead,
—— tin,
—— copper,
—— bifmuth,

Oxide

† See *Bergman* and *Lavoifier.*
‡ *Dr Hope, Tranf. Edin.* iv.
§ *Vauquelin, Ann. de Chim.* xxii. 208.

Then fince the increafe of denfity does not change the weight of the whole, $\overline{1-x} \times a + b\,x = \overline{1-4cx+4cx^2} \times y$.

$$\text{Hence } x = 0,5 - \frac{a-b}{8cy} + \sqrt{\frac{a-y}{4cy} + \left(\frac{a-b}{8cy} - 0,5\right)}$$

$$y = \frac{a-ax+bx}{1-4cx+4cx^2}$$

And making $a = 1$, $b = 0,8199$, $c = 0,0288$

$$x = 0,5 - \frac{0,1801}{0,2304\,y} + \sqrt{\frac{1-y}{0,1152\,y} + \left(\frac{0,1801}{0,2304\,y} - 0,5\right)}$$

$$y = \frac{1-0,1801\,x}{1-0,1152\,x+0,1152\,x^2}.$$

See *Irifh Tranf.* III.

Sulphurous Acid.

Oxide of antimony,
——— arſenic,
——— 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 potaſs. By this method he obtained a combination of potaſs 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 potaſs 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 Bergman, is 0,00246 *; according to Lavoiſier, 0,00251 †. 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*. 405 Its combinations,

Its affinities, as far as they have been inveſtigated, are as follows ‡: 406 And affinities.

Barytes,
Lime,
Potaſs,
Soda,
Magneſia, }
Ammonia, }
Alumina,
Jargonia * ?
Metallic oxides,
Water.

* On *Elective Attraction*, § 13.
† *Chemiſtry, Appendix.*
‡ *On Air*, ii. 330.
§ *Nicholſon's Journal*, i. 313.
‖ *Berthollet, Ann. de Chim.* ii. 56.
¶ *Fourcroy* and *Vauquelin, Nicholſon, ibid.*
* *Ibid.*
† *Ibid.*
‡ *Ibid.*
* *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.

ted *aqua fortis* and *spirit of nitre*. The name *nitric acid* was first given it in 1787 by the French chemists.

408 Method of procuring it.

Nitric acid is generally obtained in large manufactories by distilling a mixture of nitre (T) 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 *.

* *Scheele.*

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.

409 Discovery of its component parts.

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 atmospherical 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 atmospherical 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 (U) 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.

* *Veget. Statics,* ii. 284.

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 ($\frac{1}{14}$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 †.

† *Phil. Trans.* 1784.

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 *: 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).

* *Mem. Par.* 1776, p. 673.

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?

† *Encyc. Method. Chim. Acide Nitrique.*

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 ‡.

‡ *Phil. Trans.* 1783.

These experiments were immediately repeated by Messrs Van Marum and Van Trooftwyk, and with nearly the same result.

The most convenient method of performing them is the following: Take a glass tube, the diameter of which

(T) Nitre is composed of nitric acid and potass.

(U) 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.

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 bason 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 potass 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 potass will be found converted into nitre. Mr Cavendish actually saturated the potass 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 potass 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 atmospherical 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 *.

* *Phil. Trans.* 1788.

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.

410 Its properties.

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.

411 Its strength at different specific gravities.

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

Now, how much water does nitric acid contain, the density of which is 1,5543?

412 Quantity of real acid contained in concentrated nitric acid.

Mr Kirwan dried a quantity of crystallized carbonat 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 17,668 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 *.

* *Irish Trans.* iv.

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 of

Nitric Acid.

of water may be greater. He has rendered it probable, however, that nitrat of soda contains very little water.

413 Its action on other bodies,

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 Academicians*, and *Cornette*.

† *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 combinations,

Nitric acid combines with alkalies, alkaline earths, alumina, and jargonia, and with the oxides of metals, and forms compounds which are called *nitrats*. It does not act upon silica nor adamanta.

415 And affinities.

The order of its affinities is as follows:

- Barytes,
- Potass,
- Soda,
- Strontites ‡,
- Lime,
- Magnesia,
- Ammonia,
- Alumina,
- Jargonia §?
- 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 acid.

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.

* *Scheele, Crell's Annals* 1786.

417 Its properties.

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 (y), was afterwards confirmed by Mr Cornette.

§ *Ibid.* p. 144.

‖ *Ibid.* p. 156.

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. Transf.* 1797. Morveau had made the same observation in the *Elemens de Chimie de l'Academie de Dijon*.

(y) 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 spurting 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*.

Nitrous Gas.

Of 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 *.

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 ‡.

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 dminished 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 §.

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 potass, which, as Morveau has discovered, absorbs, on the application of heat, the whole oxygen in a given bulk of air almost instantaneously.

420 The eudiometer.

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.

421 Manner in which azot and oxygen are combined. 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 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 Oxygen	form nitrous gas;
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.

Muriatic Acid.

Sect. V. *Of Muriatic Acid.*

Muriatic acid appears to have been known to Basil Valentine; but Glauber was the first who extracted it from 422 Discovery of muriatic acid.

* *On Phlogiston*, p. 28.

† *Priestley*, i. 365.

‡ *Ibid.* p. 407.

§ *Nicholson's Jour.* ii. 72.

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 *marine acid*, and now, pretty generally, *muriatic acid* *.

* From *muria.*

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.

Oxy-muriatic Acid.

425
Its action on other bodies.

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 *.

* *Priestley*, ii. 281.

It is capable of dissolving a little sulphat and fluat † of lime, and arseniat of mercury.

† See sect. ix.

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*.

426
Destroys putrid miasmata.

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 †.

† *Jour. de Phys.* i. 436.

427
Its affinities.

The affinities of muriatic acid are as follow:

Barytes,
Potass,
Soda,
Strontites §,
Lime,
Magnesia,
Ammonia,
Alumina,
Jargonia ‖,
Metallic oxides as in sulphuric acid,
Water.

§ *Dr Hope.*

‖ *Vauquelin, Ann. de Chim.* xxii. 208.

Sect. VI. *Of Oxy-muriatic Acid.*

428
Discovery and preparation 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 muriat of barytes, 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.

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, $\frac{4}{7}$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 temperature of 43°, is 1,003 *. Water impregnated with it has not an acid, but an auſtere taſte †, unlike that of other acids.

* Journ. de Phyſ. 1785.
† Journ. de Phyſique, xxxvii. 382.

* Berthollet, Journ. de Phyſ. 1785.
† Scheele.

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 *.

* Morveau, Encyc. Method. Chimie, i. 251.

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.

431 Nitro-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.

432 Its action on other bodies.

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 §.

§ Bergman.

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 ‖.

‖ Journ. de Phyſique, xxxvii. 385.

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-mariats*.

433 Its affinities. The affinities of this acid, according to Lavoisier, are as follows:

Alumina,
Jargonia * ?
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,
Potass,
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-muriat 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?

Phosphoric Acid.

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 Discovery 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 Leminton Priors. *Manchester Memoirs*, vol. V. part 1st.

Phosphoric Acid.

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 $133\frac{1}{4}$ deg. he added successively small quantities of phosphorus, about 10 or 12 grains at a time, until he had dissolved $2\frac{1}{4}$ 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 $2\frac{1}{2}$ ounces of phosphorus; the remaining $\frac{1}{4}$ ounce being supposed to have evaporated. The quantity of oxygen imbibed he reckons at $3\frac{1}{2}$ ounces, and the quantity of water at about 2 ounces.

* On Fire, § lxxvii.
† Mem. Acad. 1780.

Lavoisier computes that phosphoric acid contains 100 parts of phosphorus and 154 of oxygen.

437 Its properties.

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.

‡ Bergman.
§ Morveau.

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 ||.

|| Keir's Dictionary.

438 Its action on other bodies.

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.

Boracic Acid.

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 *phosphats*.

Phosphoric acid, by the assistance of heat, is capable of decomposing glass.

439 Its affinities.

Its affinities are as follows:

Lime,
Barytes,
Strontites*,
Magnesia,
Potass,
Soda,
Ammonia,
Alumina,
Jargonia †,
Metallic oxides as in sulphuric acid,
Water.

* Hope, Trans. Edin. iv.
† Vauquelin, Ann. de Chim. xxii. 208.

440 Phosphorous acid.

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.*

441 Borax.

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 soldering 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 *tincal*. 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* ‡.

‡ Kirwan's Mineralogy, ii. 37.

442 Discovery of boracic acid.

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 Lemery the Younger soon after discovered, that it could likewise be obtained from borax by means of the nitric and muriatic acids. Geoffroi afterwards discovered, that

(E) We have observed, however, that when very much concentrated it destroyed the texture of vegetable substances, paper for instance, very completely.

Boracic 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;

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 Beaumé'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.

* *Journ. de Phys.* 1782.

444 And to prove that it is phosphoric acid.

Messrs Exschaquet 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 properties.

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.

* *Reuss De Sale Sedat.* 1778.

According to Reuss, 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.

Its specific gravity is 1,479 ‡.

‡ *Kirwan's Miner.* ii. 4.

Fluoric Acid.

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 soot 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 *.

* *Keir's Dictionary.*

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 †.

† *Ibid.*

It is hardly capable of oxidating or dissolving any of the metals except iron and zinc, and perhaps copper. 447 Its action on other bodies.

Boracic acid combines with alkalies, alkaline earths, and alumina, and most of the metallic oxides, and forms compounds, which are called *borats*.

Its affinities are as follows: 448 Its affinities.

Lime,
Barytes,
Strontites ‡,
Magnesia,
Potass,
Soda,
Ammonia,
Oxide of zinc,
——— iron,
——— lead,
——— tin,
——— cobalt,
——— copper,
——— nickel,
——— mercury,
Alumina,
Jargonia §,
Water,
Alcohol.

‡ *Dr Hope, Transf. Edin.* iv.

§ *Vauquelin, Ann. de Chim.* xxii. 208.

Sect. IX. *Fluoric Acid.*

449 Discovery of 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.*

450 Method of obtaining it.

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, 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 Sheele's own words.

452 Refuted by Scheele,

"I melted together (says he) in a crucible two ounces of finely pulverized fluor spar with four ounces of potass. 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 adopted, 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 incrusted 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 *."

* *Crell's Journal*, i. 222. Eng. Transl.

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 Leonhardi, in the 6th volume of his late learned edition of Macquer's Dictionary.

† *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 deposites at the same time a quantity of silica.

Water impregnated with this gas does not freeze at a higher temperature than 23° *.

* Priestley, ii 362.

455 Its action on other bodies.

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 †.

† Ibid.

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.

456 Its affinities.

The affinities of fluoric acid are as follows:

Lime,
Barytes,
Strontites ‡,
Magnesia,
Potass,
Soda,
Ammonia,
Oxide of zinc,
——— manganese §,
——— iron,
——— lead,
——— tin,
——— cobalt,
——— copper,
——— nickel,
——— arsenic,
——— bismuth,
——— mercury,
——— silver,
——— gold,
——— platinum,
Alumina,
Jargonia ‖ ?
Water,
Silica,
Alcohol.

‡ Dr Hope.

§ Lavoisier.

‖ Vauquelin, Ann. de Chim. xxii. 208.

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.

457 Discovery of carbonic acid.

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*, aud 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; 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 atmospherical 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*.

* Keir's Macquer, art. Air.

458 Theories about its composition.

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.

459 Its analysis.

If any thing was still wanting to put this conclusion beyond the reach of doubt, it was to *decompound* 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

(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 Broigniart (I) *.

* *Ann. de Chim.* xiii. 312.

Carbonic acid may be obtained by pouring sulphuric acid upon chalk, and receiving the product in a pneumatic apparatus.

460 Its properties,

It is invisible and elastic like common air. It extinguishes a candle, and is unfit for respiration. It has no smell.

Its specific gravity is 0,0018 †; but this varies according to its dryness or moisture.

† *Bergman*, i. 9.

It reddens the tincture of turnsole, but no other vegetable colour ‡.

‡ *Ibid.*

Atmospheric air contains about $\frac{1}{100}$ part of this gas (K).

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 ‡.

† *Brugnatelli, Nicholson's Journal*, i. 446.

‡ *Ann. de Chim.* iii. 91.

It is absorbed by red hot charcoal, as Morozzo and La Metherie have shewn.

461 Compounds,

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 jargonia, according to Klaproth *; but, according to Vauquelin, it has †.

* *Journ. de Phys.* xxxvi. 186.

† *Ann. de Chim.* xxii. 204.

462 And affinities.

Its affinities, as arranged by Bergman, are as follows:

Barytes,
Lime,
Strontites ‡,
Potass,
Soda,
Magnesia,
Alumina,
Metallic oxides as in *sulphuric acid*,
Oxygen gas §,
Water,
Alcohol.

‡ *Dr Hope.*

§ *Mr Welter.*

Acetous Acid.

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.

463 Lowitz's method of obtaining pure acetous acid.

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 ||.

|| *Crell's Journal*, i. 242. Eng. Transl.

"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 still

(I) Count Mussin-Puschin having boiled a solution of carbonat of potass 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.

(K) 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 baſon 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 carbonat of potaſs and water, till all at once a cloudineſs or precipitation appears. Although, on the appearance of this ſign, the acid is already ſuperſaturated 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.

"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 90th 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."

464 Action of acetous acid on other bodies.

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*.

465 Its affinities.

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 *,
Jargonia † ?
Water,
Alcohol,

* *Lavoiſier.*
† *Vauquelin, Ann. de Chim.* xxii. 208.

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.

466 Compoſition of ſugar.

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 parts of hydrogen, 64 of oxygen, and 28 of carbon.

467 Diſcovery of oxalic acid.

From ſugar, by a particular proceſs, an acid has been 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.

* *Elwart's Magazine for Apothecaries*, 1785, Part i. p. 54.
† *Keir's Dictionary.*

468 Method of procuring it.

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 $1\frac{1}{4}$ 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, $\frac{1}{2}$ dr. 13 gr. of ſolid acid will be obtained. If the proceſs be repeated

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.

† Encyc. 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 $\frac{3}{10}$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 $\frac{1}{50}$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*. 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.

Tartarous Acid.

* Bergman.

When nitric acid is frequently distilled off oxalic acid, acetous acid is produced †. The sulphuric acid, when concentrated, seems to produce the same effect. Muriatic and acetous acids dissolve oxalic acid, but without altering it ‡.

† Westrum.

‡ Bergman.

470 Its action on other bodies.

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 alkalies, alkaline earths, and alumina, and metallic oxides, and forms salts known by the name of *oxalats*.

471 Its affinities.

Its affinities, according to Bergman, are as follows:

Lime,
Barytes,
Strontites §,
Magnesia,
Potass,
Soda,
Ammonia,
Alumina,
Jargonia || ?
Metallic oxides as in *sulphuric acid*,
Water,
Alcohol.

§ Dr Hope, Trans. Edin. iv.

|| Vauquelin, Ann. de Chim. xxii. 208.

Sect. XIV. *Of Tartarous Acid.*

472 Discovery 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 potass: 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 tartrite of lime thus formed by means of sulphuric acid.

473 Its properties.

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 Packen, they assume oftenest the form of long pointed prisms †; Spielman and Corvinus ‡ obtained them in groups, some of them lance-shaped, others needle-formed, others pyramidal. Morveau obtained them needle-form §. They do not experience any change in the air; heat

* Bergman, iii. 308.

† De Sale Essent. acidi Tartari.

‡ Analecta de Tartaro.

§ Encyc. Method. Chim. i. 323.

Citric Acid.

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, ibid and ii. 465
† Spielman and Corvinus, ibid.
‡ Hermstadt and Westrum.

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.

§ Bergman, i. 250.

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 alkalies, 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 occicoccos, 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 towards 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's Journal, ii. 43.
* Nicholson, ibid.

477 Its properties.

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.

† Dizé, ibid.

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 ‡.

‡ Id. ibid.

Citric acid has a very acid taste; it turns vegetable blues to a red.

478 Its action on other bodies.

It is capable of oxidating iron, zinc, tin. It does not act upon gold, silver, platinum, mercury, bismuth, antimony, arsenic.

It combines with alkalies, 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.

479 Its affinities.

The affinities of this acid are as follows §:

Lime (L),
Barytes,
Strontites ‖,
Magnesia,
Potass,
Soda,

§ See Bergman and Lavoisier.
‖ Dr Hope, Transf. Edin. iv.

(L) Mr De Breffey places barytes before lime.

Soda,
Ammonia,
Oxide of zinc,
——— manganeſe *, * *Lavoiſier.*
——— iron,
——— lead,
——— cobalt,
——— copper,
——— arſenic,
——— mercury,
——— antimony †, † *Id.*
——— ſilver,
——— gold,
——— platinum,
Alumina ‡, ‡ *Id.*
Jargonia § ? § *Vauquelin, Ann de Chim.* xxii. 208.
Water,
Alcohol.

SECT. XVI. *Of Malic Acid.*

480 Diſcovery of malic acid. SCHEELE diſcovered a peculiar acid in the juices of ſeveral fruits, which, becauſe it is found moſt abundantly 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 potaſs, 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 Annals for* 1785.

This acid is contained in the berries of the *barberis vulgaris*, the *ſambucus nigra*, the *prunus ſpinoſa*, the *ſorbus aucuparia*, and the *prunus domeſtica* ¶.

¶ *Ibid.*

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 proper quantity of nitric acid †.

* *Ibid.*

† *Hermſtadt, Phyſ. Chem.*

482 Its properties. This acid bears a ſtrong reſemblance to the citric, but differs from it in the following particulars:

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.

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 alkalies, alkaline earths, and alumina, and metallic oxides, and forms ſalts known by the name of *malats.* 483 Its combinations.

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 ſour whey to an eighth part, 484 Method of obtaining lactic acid. and then filtrate it: this ſeparates the cheeſy part. Saturate 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 into 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 ſolution 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 *.

* *Scheele, Stockholm Tranſ.* 1780.

This acid is incapable of cryſtallizing: when evaporated to dryneſs, it deliqueſces again in the air †.

† *Ibid.*

When diſtilled, water comes over firſt, then a weak 485 Its properties. 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 ‡.

‡ *Ibid.*

The combinations which this acid forms with alkalies, earths, and metallic oxides, are called *lactats.* 486 Combinations,

Its affinities, according to Bergman, are as follows: 487 And affinities.

Barytes,
Potaſs,
Soda,
Ammonia,
Lime,
Magneſia,
Alumina,
Jargonia § ? § *Vauquelin, Ann. de Chim.* xxii. 208.
Metallic oxides as in *ſulphuric acid,*
Water,
Alcohol.

SECT. XVIII. *Of Saccholactic Acid.*

488 Sugar of milk. IF a quantity of freſh whey of milk be filtrated, and then evaporated by a gentle fire till it is of the conſiſtence of honey, and afterwards allowed to cool, a ſolid maſs

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 deposites 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.

489 Method of obtaining saccholactic acid.

After Mr Scheele had obtained oxalic acid from sugar, 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 being edulcorated 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.

According to Scheele, it is soluble in 60 parts of its weight of boiling water; but Messrs Hermstadt * and Morveau † found, that boiling water only dissolved $\frac{1}{80}$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 ‖.

* *Phys. Chem.*
† *Encyc. Method.* i. 290.
‡ *Scheele.*
§ *Id.*
‖ *Morveau, ibid.*

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 Hermstadt found to contain a small quantity of lime. Concentrated sulphuric acid distilled on this salt becomes black, frothes, and decomposes it †.

* *Scheele, ibid.*
† *Id. ibid.*

491 Hermstadt attempts to disprove its existence.

Mr Hermstadt 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.

‡ *Morveau, Encyc. Method.* i. p. 291.

492 Its compounds and affinities.

Its compounds with alkalies, earths, and metallic oxides, are denominated *saccholats*.

Its affinities, according to Bergman, are as follows:

Lime,
Barytes,
Magnesia,
Potass,
Soda,
Ammonia,
Alumina,
Jargonia §?
Metallic oxides as in *sulphuric acid*,
Water,
Alcohol.

§ *Vauquelin, Ann. de Chim.* xxii. 208.

Sect. XIX. *Of Gallic Acid.*

493 Nut-galls.

There is an excrescence, known by the name of *nutgall*, 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

(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 being edulcorated with cold water, rediſſolved in hot water, filtrated, and evaporated very ſlowly, yielded an acid ſalt in cryſtals as fine as ſand*.

* *Stockholm Tranſ.* 1786.

There is a ſhorter method of obtaining this acid in a ſtill purer ſtate than Scheele obtained it.

495 Method of obtaining 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 J. J. Dizé Jour. de Phyſ.* Dec. 1791.

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.

‡ *Ann. de Chim.* xvii. 8.

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.

§ *Ibid.*

496 Prouſt's method.

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.* xxv. 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. 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.

498 Its compoſition.

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.*

499 Benzoin.

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 benzoin*, becauſe it was obtained by ſublimation. This acid, which is now called *the benzoic acid*, may be ſublimed from benzoin by heat; or it may be obtained by

Scheele's

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 Its combinations and affinities.

Little is known respecting its base.

It combines with alkalies, earths, and metallic oxides, and forms salts known by the name of *benzoats*.

Its affinities, from the experiments of Trommsdorf, appear to be as follows:

White oxide of arsenic,
Potass,
Soda,
Ammonia,
Barytes,
Lime,
Magnesia,
Alumina,
Jargonia ‡?
Water,
Alcohol.

* *Morveau, Encyc. Method. Chim.* i. 44.
† *Lichtenstein.*
‡ *Idem.*
§ *Morveau, ibid.*
|| *Lichtenstein.*
¶ *Id.*
* *Id.*
† *Id.*
‡ *Vauquelin, Ann. de Chim.* xxii. 208.

Sect. XXI. *Of Succinic Acid.*

502 Amber.

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*.

§ *Boyle abridged by Shaw*, iii. 369.

Camphoric Acid.

503 Method of obtaining succinic acid.

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.

* *Bergman's Notes on Scheffer.*

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 504 Its properties, 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 ¶.

505 Combinations and affinities.

The combinations of this acid are called *succinats*.

Its component parts are still unknown.

Its affinities, according to Morveau, are as follows:

Barytes,
Lime,
Potass,
Soda,
Ammonia,
Magnesia,
Alumina,
Jargonia *?
Metallic oxides as in *sulphuric acid*,
Water,
Alcohol.

† *Pott.*
‡ *Inst. Chem.* § xii.
§ *De Succino.*
|| *Morveau, ibid.* p. 72.
¶ *Wenzel.*
* *Vauquelin, Ann de Chim.* xxii. 208.

Sect. XXII. *Of Camphoric Acid.*

506 Camphor.

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.

† *Ann. de Chim.* iv. 179.
‡ *LaGrange, ibid.* xxiii. 153.

If

Camphoric Acid.

If one part of camphor and ſix parts of pulveriſed 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 decompounded, 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.* xxiii. 153.

507 Oil of camphor.

The oil obtained has the following properties:

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 alkalies, 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. 1785.

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 parallelopipedons ‖.

‖ *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 $\frac{1}{12}$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. 40

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.

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 alkalies, earths, and metallic oxides, which are called *camphorats*. 510 Its combinations and affinities.

Its affinities, as far as aſcertained by La Grange, are as follows *:

* *Ann. de Chim.* xxvii. 21.

Lime,
Potaſs,
Soda,
Barytes,
Ammonia,
Alumina,
Magneſia.

Sect. XXIII. *Of Suberic Acid.*

Cork, a ſubſtance too well known to require any 511 Diſcovery of ſuberic acid.
deſcription, is the bark of a tree which bears the ſame name. By means of nitric acid, Brugnatelli converted it into an acid †, which has been called the *ſuberic acid*, from *Suber*, the Latin name of the cork-tree. Several chemiſts affirmed that this acid was the oxalic, becauſe 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.

† *Crell's Annals*, 1787.

To prepare it, a quantity of ſound cork grated down 512 Method of preparing it.
ſmall is to be put into a retort, ſix times its weight of nitric acid of the ſpecific gravity 1,261 poured upon 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.

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 depoſites 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 potaſs 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 potaſs 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 $\frac{1}{144}$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 ſebacic acid (O).

It is not altered by oxygen gas:—the other acids do not diſſolve it completely. Alcohol developes an aromatic odour, and an ether may be obtained by means of this acid.

It converts the blue colour of nitrat of copper to a green; the ſulphat of copper alſo to a geen; green ſulphat of iron to a deep yellow; and ſulphat of zinc to a golden yellow (P).

514 Its action on other bodies.

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.

With alkalies, earths, and metallic oxides, it forms compounds known by the name of *ſuberats*.

515 Its affinities.

Its affinities are as follows (Q):

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 alkalies.

(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 alkalies, 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,
Magnefia,
Alumina *.

* Ann. de Chim. xxiii. 42.

Mr Bouillon La Grange, to whom we are indebted for all the facts relative to this acid, fuppofes that it is compofed of oxygen, hydrogen, and carbon: but Mr Jamefon, in confequence of the refult of a feries of experiments which he made on charcoal, has been led to fufpect that it confifts entirely of carbon and oxygen. He found, that by the action of nitric acid upon charcoal, a brown, bitter, deliquefcent mafs was formed, foluble in water, alcohol, and alkalies, and which emitted, particularly when heated, a very fragrant odour. This matter was more or lefs foluble in water according to the time that it had been expofed to the action of the acid. When the nitric acid ufed was concentrated, and confiderable in quantity, part of the charcoal was converted into an acid, which poffeffed the characters of the fuberic †.

516 Its compofition.

† *Jamefon's Mineralogy of Shetland and Arran*, p. 167.

These facts are curious, and may extend our knowledge of the nature of vegetable acids, but they are infufficient to prove the abfence of hydrogen in fuberic acid, becaufe charcoal cannot eafily be procured perfectly free from hydrogen, and becaufe feveral of the properties of fuberic acid indicate the prefence of hydrogen in it, its becoming brown, for inftance, when expofed to the light. Mr Jamefon has obferved, that the acid which exifts ready formed in peat poffeffes the properties of fuberic acid.

Sect. XXIV. *Of Laccic Acid.*

517 Difcovery of white lac.

About the year 1786, Dr Anderfon of Madras mentioned, in a letter to the governor and council of that place, that nefts of infects, refembling fmall cowry fhells, had been brought to him from the woods by the natives, who eat them with avidity. Thefe fuppofed nefts he foon afterwards difcovered to be the coverings of the females of an undefcribed fpecies of coccus, which he fhortly found means to propagate with great facility on feveral of the trees and fhrubs growing in his neighbourhood (R).

On examining this fubftance, which he called *white lac*, he obferved in it a very confiderable refemblance to bees wax; he noticed alfo, that the animal which fecretes it provides itfelf by fome means or other with a fmall quantity of honey, refembling 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 fweetnefs to eat fo much of it as materially to reduce the produce of his crop. Small quantities of this matter were fent into Europe in 1789, both in its natural ftate and melted into cakes; and in 1793 Dr Pearfon, at the requeft of Sir Jofeph Banks, undertook a chemical examination of its qualities, and his experiments were publifhed in the Philofophical Tranfactions for 1794.

518 Its analyfis.

A piece of white lac, from 3 to 15 grains in weight, is probably produced by each infect. Thefe pieces are of a grey colour, opaque, rough, and roundifh. When white lac was purified by being ftrained through muflin, it was of a brown colour, brittle, hard, and had a bitterifh tafte. It melted in alcohol, and in water of the temperature of 145°. In many of its properties it refembles bees wax, though it differs in others; and Dr Pearfon fuppofes that both fubftances are compofed of the fame ingredients, but in different proportions.

Two thoufand grains of white lac were expofed in fuch a degree of heat as was juft fufficient to melt them. As they grew foft and fluid, there oozed out 550 grains of a reddifh watery liquid, which fmelled like newly baken bread (s). To this liquid Dr Pearfon has given the name of *laccic acid* *.

* *Pearfon's Tranf. of the Chemical Nomenclature.*

519 Properties of laccic acid.

It poffeffes the following properties:

It turns paper ftained with turnfole to a red colour.

After being filtered, it has a flightly faltifh tafte with bitternefs, but is not at all four.

When heated, it fmells precifely like newly baken hot bread.

On ftanding, it grows fomewhat turbid, and depofites a fmall quantity of fediment.

Its fpecific gravity at the temperature of 60° is 1,025.

A little of it having been evaporated till it grew very turbid, afforded on ftanding fmall needle-fhaped cryftals in mucilaginous matter.

Two hundred and fifty grains of it were poured into a very fmall retort and diftilled. As the liquor grew warm, mucilage-like clouds appeared; but as the heat increafed they difappeared again. At the temperature of 200°, the liquor diftilled over very faft: A fmall quantity of extractive matter remained behind. The diftilled liquor while hot fmelled like newly baken bread, and was perfectly tranfparent and yellowifh. A fhred of paper ftained with turnfole, which had been put into the receiver, was not reddened; nor did another which had been immerfed in a folution of fulphat of iron, and alfo placed in the receiver, turn to a blue colour upon being moiftened with the folution of potafs (T).

About

Oxide of Iron.	Oxide of Bismuth.	Oxide of Arsenic.
* * *	* * *	* * *
Sulphuric,	Muriatic,	Nitric acid,
Suberic.	Suberic.	Suberic.

Cobalt and Zinc the fame with arfenic.

(R) The Chinefe collect a kind of wax, which they call *pe-la*, from a coccus, depofited for the purpofe of breeding on feveral fhrubs, and manage it exactly as the Mexicans manage the cochineal infect. It was the knowledge of this that induced Dr Anderfon to attempt to propagate his infect.

(s) The fame liquid appears on preffing 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 pruffic.

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 effervеſcence. The ſolution taſted bitteriſh, did not turn paper ſtained with turnſole red, and on adding to it carbonat of potaſs 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 potaſs.

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 effervеſcence 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 potaſs, 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.

Tartrite of potaſs produced a precipitation not unlike what takes place on adding tartarous acid to tartrite of potaſs (u); but it did not diſſolve again on adding potaſs.

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 tartrite of potaſs without forming tartar, its bitteriſh taſte, and its being converted into vapour at the temperature of 200°, diſtinguiſh it from all the acids hitherto examined *.

* Phil. Tranſ. 1794, p. 383.

Pyromucous Acid.

Sect. XXV. *Of Pyromucous Acid.*

520 Method of obtaining 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, potaſs, for inſtance, and decompoſing the compound by a ſtronger acid, as, for example, the ſulphuric.

521 Its properties,

It has a very ſharp taſte. When expoſed to heat in open veſſels, it evaporates, leaving a brown ſpot. Diſtilled 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.

† Schrickel.

522 Combinations, and affinities.

The compounds which it forms are called *pyromucites*.

Its affinities, according to Morveau, are as follows:

Potaſs,
Soda,
Barytes,
Lime,
Magneſia,
Ammonia,
Alumina,
Jargonia ‡.
Metallic oxides as in *ſulph. acid*,
Water,
Alcohol.

‡ Vauquelin, Ann. de Chim. xxii. 208.

Sect. XXVI. *Of Pyro-lignous Acid.*

523 Method of obtaining 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 pyrolignous 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

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(u) On this addition, tartar, or acidulated tartrite of potaſs, is formed, which precipitates, becauſe it is very little ſoluble in water. The addition of potaſs diſſolves it again.

(v) Morveau called this acid *ſyrupous* acid.

(w) Goettling called it *ligneous acid.*

Pyro-ligneous 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 potaſs, 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 potaſs. 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.

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.

524 Its properties, combinations, and affinities.

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 Bourſier de Clervaux and Mr de Morveau, are as follows:

Lime,
Barytes,
Potaſs,
Soda,
Magneſia,
Ammonia,
Oxide of zinc,
——— manganeſe,
——— iron,
——— lead,
——— tin,
——— cobalt,
——— copper,
——— nickel,
——— arſenic,
——— biſmuth,
——— mercury,
——— antimony,
——— ſilver,
——— gold,
——— platinum,
Alumina,
Jargonia † ?

† 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-tartrites.*

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.

527 Deſtroyed by fire.

Vegetable acids are diſtinguiſhed from all the acids deſcribed in the beginning of this chapter, by their deſtructibility by fire.

528 Convertible into each other.

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.

529 Inquiry into the proportions of their ingredients.

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.

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 potaſs, Dr Higgens obtained the following products *:

* Higgens on Acetous Acid, p. 26.

Potaſs,	- - - -	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 Higgens 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 potaſs is compoſed of acetous acid and potaſs, and ſince the whole of the potaſs 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 Higgens 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.

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

* *Hermſtadt, Crell's Annals*, 1786.

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

† *Crell, Jour. de Phyſ.* 1785.

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. Weſtrum mixed ſtrong ſulphuric acid with tartarous acid, and added mangane ſe; 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 being 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 *. Weſtrum converted it into oxalic acid by means of nitric acid.

* *Stahl.*

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 potaſs, from which that chemiſt had *diſtilled* ſeveral times his *animal oil*. On pouring in the potaſs, 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 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

530 Diſcovery of Pruſſian blue.

† *Stahl's 300 Experiments.*

531 Method of preparing it.

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.

532 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 colouring 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.

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. 533 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 *. 534 The colouring matter separated.

He then distilled in a gentle heat; the colouring matter

* *Berthollet, Ann. de Chimie*, i. 30.

Pruffic Acid.

ter came over by the time that one-fourth of the liquor had paffed into the receiver. It was mixed, however, with a fmall quantity of fulphuric acid; from which he feparated it by diftilling a fecond time over a quantity of carbonat of lime. The fulphuric acid combines with the lime and remains behind, which the colouring matter cannot do, becaufe carbonic acid has a ftronger affinity for lime than it has. Thus he obtained the colouring matter in a ftate of purity.

535 Its component parts. It remained now to difcover its component parts. He formed a very pure Pruffian blue, which he diftilled, and increafed the fire till the veffel became red. The fmall 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 confifted of azot, carbonic acid gas, and the colouring matter. He concluded from this experiment, that the colouring matter was compofed of ammonia and carbon. He mixed together equal quantities of pounded charcoal and potafs, put the mixture into a crucible, and kept it red hot for a quarter of an hour: he then added a quantity of fal ammoniac in fmall pieces, which he pufhed to the bottom of the melted mixture, kept it in the fire for two minutes till it had ceafed to give out vapours of ammonia, and then threw it into a quantity of water. The folution poffeffed all the properties of the Pruffian alkali. Thus Mr Scheele fucceeded in forming the colouring matter; and it was confidered as proved that it was compofed of ammonia and carbon.

But after the publication of Scheele's experiments, it was difcovered that ammonia itfelf is compofed of azot and hydrogen. It became therefore a queftion, Whether ammonia entered into the compofition of this fubftance, or merely its ingredients? Whether it was compofed 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 pafs through a red hot porcelain tube filled with charcoal, and by this procefs formed a quantity of the colouring matter *. Here the temperature was fo high that the ammonia muft have been decompofed: and the colouring matter cannot be formed by combining ammonia and charcoal except at a temperature equally high. There is reafon therefore to fuppofe that the ammonia is decompofed. When oxy-muriatic acid is mixed with the colouring matter, it communicates to it a quantity of oxygen, and caufes it in confequence to affume very different properties. When a fixed alkali or lime is added to it in this ftate, it is immediately decompofed, and converted into ammonia and carbonic acid gas. The colouring matter in this ftate contains all the ingredients neceffary to form thefe two fubftances, namely, azot, hydrogen, carbon, oxygen: but in order to induce the ingredients to form thefe two compounds, the affiftance of an alkali or lime to combine with the carbonic acid is neceffary; juft as fulphur combines more eafily with oxygen when united with an alkali or with iron than when feparate †.

* *Ann. de Chim.* xi.

† *Bertholle*t, *ibid.* i.

The colouring matter, then, which we fhall henceforth call the *Pruffic acid*, is compofed of azot, hydrogen, and carbon; but the proportions of thefe ingredients have not yet been determined. It is confidered as an acid, though the prefence of oxygen has not been proved, becaufe it has the property of forming neutral falts with the fame bafes as other acids.

The Pruffic acid is exceedingly volatile, and evidently capable of exifting in a gafeous ftate. It has a peculiar odour, not difagreeable, and which has been compared to the flowers of the peach. It has a fweetifh and fomewhat hot tafte, and excites cough*. 536 Properties of Pruffic acid.

It has no affinity for alumina nor for alcohol †.

* *Scheele.*

† *Morveau.*

This fubftance differs exceedingly in its action from all other acids.

It is capable of combining, like them, with earths, alkalies, and metallic oxides, and of forming compounds which have been denominated *Pruffiats*. But it enters much more readily into triple compounds with alkalies or earths, and metallic oxides, than into combinations with earths or alkalies feparately; and though its affinity appears to be greater for alkalies and earths than for metallic oxides, yet when in a free or gafeous ftate it does not enter into combinations with earths or alkalies without difficulty, and it is feparated from them much more eafily than from metallic oxides. Mere expofure to the light of the fun, or to a heat of 110°, is fufficient for that purpofe. 537 Its action on other bodies.

Its affinities are fuppofed to be as follows: 538 Its affinities.

Potafs,
Soda,
Ammonia,
Lime,
Barytes,
Magnefia,
Oxide of zinc,
——— iron,
——— manganefe,
——— cobalt,
——— nickel,
——— lead,
——— tin,
——— copper,
——— bifmuth,
——— antimony,
——— arfenic,
——— filver,
——— mercury,
——— gold,
——— platinum (Y).

Sect. XXIX. *Of Formic Acid.*

In the 15th century feveral botanifts obferved, with aftonifhment, that the flower of fuccory, when thrown into an ant hill, became as red as blood: But it was Mr S. Fifher who firft difcovered that ants poffeffed a peculiar acid, which he obtained by diftilling thefe animals. His experiments were publifhed in the Philofophical Tranfactions for 1670. Though Hoffman afterwards repeated 539 Difcovery of formic acid.

(Y) We fufpect that this is not the real order of the affinities of this acid; the metallic oxides ought probably to be placed before the alkalies and earths, and the metallic Pruffiats ought to occupy the place which is at prefent filled by the metallic oxides. The reafons for this conjecture will appear afterwards. See Part III. chap. ii. fect. 23. of this article.

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.

540 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 Ardviſſon 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.

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 Ardviſſon 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 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 §.

541 Its properties.

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.

* Diſſert. on the Acid of Ants, 1777, in Baldinger's New Magazine for Arts.

† Encyc. Method. i. 61.

‡ Ardviſſon and Oehrn, ibid.

§ Crell's Annals, 1784.

‖ Ibid.

¶ Ardviſſon, ibid.

* Ibid.

† Morveau, p. 62.

Sebacic Acid.

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*. 542 Its compounds and affinities.

Its affinities are the ſame with thoſe given above for the Pruſſic acid.

* Ibid.

† Ibid.

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. Grutzmacher 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. Tranſ. for 1780 and 1782. It was called at firſt *acid of fat*, and afterwards *ſebacic acid*. 543 Diſcovery of ſebacic acid.

‡ Leonhardi.

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, mangan eſe.

It does not act upon biſmuth, cobalt, nickel. When mixed with nitric acid it diſſolves gold.

Its compounds are called *ſebats*. 545 Compounds and affinities.

Its affinities, according to Morveau, are as follows:

Barytes,
Potaſs,
Soda,
Lime,
Magneſia,
Ammonia,
Alumina,
Jargonia §,
Oxide of zinc,
——— mangan eſe,
——— iron,
——— lead,
——— tin,
——— cobalt,
——— copper,
——— nickel,
——— arſenic,
——— biſmuth,
——— mercury,
——— antimony,
——— ſilver.

§ 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 *muſcadine*, was acid; and Chauſſier remarked, that the ſilkworm, after being converted into a butterfly, gives out a 546 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 cocon, the acid was depofited in a refervoir near the anus. By means of a pair of fciffars he collected fome which reddened blue paper, united with alkalies with effervefcence, and even attacked the fciffars. He afterwards collected it by infufing the chryfalids in alcohol, which diffolved the acid, but left the impurities untouched.

This acid has never been examined with attention; fo that almoft all its properties are unknown.

Sect. XXXII. *Of Zoonic Acid.*

547 Method of obtaining zoonic acid.

Mr Berthollet has obtained a peculiar acid by diftilling vegetable and animal fubftances, to which he has given the name of the *zoonic acid* *. He procured it by diftilling the gluten of wheat, the yeft of beer, bones, and woollen rags; and concludes, therefore, that it may be produced by the diftillation of all animal fubftances.

* *Ann. de Chim.* xxvi. 86.

To obtain this acid pure, he mixed lime with the diftilled liquid, after having feparated the oil, which it always contains (for the product of the diftillation of animal fubftances is chiefly oil and carbonat of ammonia.) He boiled this mixture till the carbonat of ammonia was exhaled: he then filtered it, added a little more lime, and boiled it again till the fmell 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 diffolved in the liquid without being combined with the zoonic acid.

After concentrating the zoonat of lime, he mixed it with phofphoric acid, and diftilled it in a retort. At a heat nearly equal to that of boiling water, the zoonic acid paffes over in a ftate of purity.

548 Its properties.

The zoonic acid has an odour like that of meat when frying, and it is actually formed during that procefs. It has an auftere tafte.

It gives a red colour to paper tinged with turnfole.

With alkalies and earths it produces falts, which do not appear capable of cryftallizing.

It forms a white precipitate in the folutions of acetite of lead and nitrat of mercury.

Part of the zoonic acid feems to be deftroyed by the action of heat during the diftillation of the zoonat of lime with phofphoric 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 filver, when kept, becomes gradually brown; hence he concludes that the acid contains hydrogen. Thefe conclufions he draws from a very ingenious theory of his, which has been already defcribed 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*, becaufe they are all obtained from the animal kingdom. It can fcarcely be doubted that a more accurate examination of animal fubftances will add confiderably to the number of thefe acids.

Sect. XXXIII. *Of Arfenic Acid.*

Arsenic acid, which was firft difcovered by Scheele, may be produced by fimply mixing the white oxide of arfenic with oxy-muriatic acid, and applying a heat fufficient to fublime the muriatic acid. The theory of this operation is evident: the white oxide has a greater affinity for oxygen than muriatic acid has; of courfe it combines with it, and is thus converted into arfenic acid, and the muriatic acid is eafily fublimed by applying heat.

Arfenic Acid.

550 Method of obtaining arfenic acid.

Landriani has informed us, that this acid may be alfo formed by fubliming feveral times fucceffively the white oxide of arfenic, and taking care every time to renew the air. This procefs is equally fimple; the oxide combines at a high temperature with the oxygen of the atmofphere.

551 Its properties.

This acid is exceedingly fixed. When expofed to the air it attracts humidity, and at laft becomes liquid. At the temperature of 60° it diffolves in two-thirds of its weight of water. Its folution may be evaporated to drynefs, and even converted into a glafs, which attracts moifture from the air, and acts powerfully on the crucible.

It is poifonous as well as the white oxide of arfenic *.

* *Scheele.*

When expofed to a red heat, it is partly decompofed and converted into white oxide of arfenic †.

† *Id.*

It does not act upon gold, platinum, filver, mercury.

It oxidates copper, iron, lead, tin, zinc, bifmuth, antimony, cobalt, nickel, manganefe, and arfenic, and in a very ftrong heat, mercury and filver.

According to Berthollet's experiments, arfenic acid is compofed of eight parts of white oxide of arfenic and one part of oxygen.

552 Its compounds and affinities.

Its compounds are called *arfeniats*.

Its affinities are as follows:

Lime,
Barytes,
Magnefia,
Potafs,
Soda,
Ammonia,
Oxide of zinc,
——— manganefe,
——— iron,
——— lead,
——— tin,
——— cobalt,
——— copper,
——— nickel,
——— bifmuth,
——— mercury,
——— antimony,
——— filver,
——— gold,
——— platinum,
Alumina,
Jargonia ‡?
Water.

‡ *Vauquelin, Ann. de Chim.* xxii. 208.

Sect. XXXIV. *Of Tungstic Acid.*

553 Properties of tungftic acid.

Tungstic acid, or oxide of tungften, was firft difcovered by Scheele; but the acid which he examined was not pure, being compofed, as Mr Luyart has fhewn, of nitric acid, ammonia, and tungftic acid. The real acid is infoluble in water, taftelefs, and incapable of turning vegetable blues red till it has been firft rendered

 foluble

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 acetous 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.

* Renman.

554 Its compounds and affinities.

Its compounds are called *tungstats*.

Its affinities are as follows †:

Lime,
Barytes,
Magnesia,
Potass,
Soda,
Ammonia,
Alumina,
Jargonia ‡ ?

† Luyarts.

‡ Vauquelin, Ann. de Chim. xxii. 208.

Sect. XXXV. *Of Molybdic Acid.*

555 Properties of molybdic acid.

Concrete molybdic acid, first discovered by Scheele, is white, and has an acid but metallic taste. Its specific gravity is 3,75 §. 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.

§ Bergman.

It may be prepared by treating the ore of molybdenum with nitric acid, and washing the acid when formed in water.

When combined with potass, 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 dipt in this acid becomes in the sun of a beautiful blue colour ‖.

Sulphur is capable of partly decomposing it by heat.

Its compounds are called *molybdats*.

Its affinities are unknown.

‖ Vauquelin, Philosophical Magazine, i. 282.

Sect. XXXVI. *Of Chromic Acid.*

Chromic Acid.

556 Analysis of the red lead of Siberia,

In the year 1770, Mr Pallas discovered in the gold mine of Beresof, near Ekaterimbourg 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 - -	$36\frac{1}{9}$
Oxygen - -	$37\frac{5}{9}$
Iron - -	$24\frac{8}{9}$
Alumina - -	2
	$100\frac{5}{9}$

and a little silver *.

Mr Bindheim of Moscow analysed it soon after, and found it to contain,

* Ann de Chim. i. 301.

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.

† Berl. Beob iv. 2911.

A hundred parts of this mineral, reduced to a fine powder, were mixed with 300 parts of the saturated carbonat of potass, 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 potass, 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 potass and the necessary quantity of water, and

Chromic Acid.

and then treated them as before, and the phenomena were the fame. The liquor, after being filtered, was united to the former; and the refiduum, wafhed and dried, weighed no more than two parts, which were ftill red lead, and therefore thrown away.

The two nitric folutions, united and evaporated, produced 92 parts of nitrat of lead, cryftallized in octahedra, perfectly white and tranfparent. Thefe 92 parts of nitrat of lead, diffolved in water, were precipitated by a folution of the fulphat of foda. This produced 81 parts of the fulphat of lead, which were equivalent to 56,68 of metallic lead.

557 And difcovery of chromic acid.

The alkaline liquors were found to contain a falt compofed of potafs combined with a peculiar acid, which Mr Vauquelin afterwards called *chromic acid*.

Thefe liquors, fubjected to evaporation until a faline pellicle was formed on their furface, produced, on cooling, yellow cryftals; among which there was a carbonat of potafs, not decompofed. Thefe cryftals, diffolved in water, and the folution united with the mother-water, the whole was mixed with weak nitric acid until the carbonat of potafs was faturated. The liquor then had a very dark orange-red colour. Being united with a folution of the muriat of tin, newly made, it firft affumed a brown colour, which afterwards became greenifh. Mixed with a folution of the nitrat of lead, it immediately produced the red lead. Laftly, evaporated fpontaneoufly, it produced ruby-red cryftals, mixed with cryftals of the nitrat of potafs. Ninety-eight parts of this mineral, decompofed as above-mentioned, having produced 81 parts of the fulphat of lead, 100 parts would have given 82,65, which are equivalent to 57,1 of metallic lead. "But admitting, as experiment proves (fays Mr Vauquelin), that 100 parts of lead abforb, 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 cryftallizes in the form of elongated prifms of a ruby colour.

When mixed with filings of tin and the muriatic acid, it becomes at firft yellowifh brown, and afterwards affumes a beautiful green colour.

When mixed with a little alcohol and nitric acid, it immediately affumes a bluifh green colour, which preferves the fame fhade even after deficcation. Ether alone gives it the fame colour.

With a folution of nitrat of mercury, it gives a precipitate of a dark cinnabar colour.

With a folution of nitrat of filver, it gives a precipitate, which, the moment it is formed, appears of a beautiful carmine colour, but becomes purple by expofure to the light. This combination, expofed to the heat of the blow-pipe, melts before the charcoal is inflamed. It affumes a blackifh and metallic appearance. If it be then pulverifed, the powder is ftill purple; but after the blue flame of the lamp is brought in contact with this matter, it affumes a green colour, and the filver appears in globules diffeminated throughout its fubftance.

With nitrat of copper, it gives a chefnut red precipitate.

With the folutions of fulphat of zinc, muriat of bifmuth, muriat of antimony, nitrat of nickel, and muriat of platinum, it produces yellowifh precipitates when thefe folutions do not contain excefs of acid. With muriat of gold, it produces a greenifh precipitate.

When melted with borax or glafs, it communicates to them a beautiful emerald green colour.

Paper impregnated with chromic acid affumes in the light a greenifh colour.

When mixed with muriatic acid, the mixture was capable of diffolving gold like aqua regia; when this mixture of the two acids is diftilled, oxy-muriatic acid is difengaged, and the liquor affumes a very beautiful green colour.

Sulphuric acid, while cold, produces no effect upon it; but when warmed, it makes it affume a bluifh green colour, probably by favouring the difengagement of oxygen.

When this acid is heated along with charcoal, it is reduced to the metal called *chromum*. It is therefore compofed 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 difcovered. Vauquelin is the only chemift who has examined it; and from his memoir the above account has been taken *.

* *Ann. de Chim.* xxv. 114. and *Philofophical Magazine*, i. 279. and 361.

The four laft defcribed acids are called *metallic acids*, becaufe they are compofed of metals and oxygen.

559 Metallic acids.

It is believed that moft of the metals, we would rather fay of the metallic oxides, are capable of being converted into acids by being combined with oxygen. It is certain that this is the cafe with platinum; and Hermftadt, by diftilling nitric acid off tin, converted it into a white mafs, foluble in three parts of water, which has been called *ftannic acid* †. Several more of the metallic oxides act the part of acids: But no complete fet of experiments on this important fubject has yet appeared.

† *Ann. de Chim.* iv. 162.

Chap. VI. *Of* Affinity.

560 Importance of affinity.

The meaning of the word *affinity* has been already explained; and it muft appear evident, from the ufe which has been made of it in this article, that the confideration of the nature of affinity is the moft important part of chemiftry. While its laws are unknown, chemiftry is not a fcience, but a wildernefs of facts without beauty or regularity: every thing is equally perplexing and incomprehenfible. The chemift, inftead of being able to trace the operations of Nature, is loft in an endlefs maze of uncertainty, without a guide to conduct him, or a ray of light to illuminate his fteps. It is the knowledge of affinity which difpels the darknefs, removes the confufion, fhews us the order which fubfifts 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 fubfervient to the improvement of the arts, and thus to render them the minifters of our comforts and enjoyments.

561 It unites bodies, particle to particle.

1. When two bodies are united together by affinity, how fmall a portion foever of the compound we examine, we fhall always find it to contain both of the ingredients. From this it is evident, that affinity combines bodies, particle with particle.

By *particles* we do not mean what philofophers have called *atoms*, or the fmalleft parts into which it is poffible to divide matter; but the fmalleft 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.

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.

564 Whether the ſame with gravitation.

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 apparently 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 potaſs, 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 potaſs without producing any decompoſition?

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.

565 No poſitive proof that it is different.

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° 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.

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 ſtudy 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

Plate XVII.

Affinity. another *may* vary in different cafes, and the force of affinity will vary with the diftance. Here then is a reafon why the affinity of different bodies varies in ftrength. Sulphuric acid, for inftance, has a ftronger affinity for barytes than for lime; becaufe when the combinations are formed, the diftance between the acid and barytes is not fo great as that between the acid and lime.

But why do the diftances differ? If affinity be the fame with gravitation, it muft 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 anfwer was firft given to the queftion by Buffon, and it is fully adequate to folve the difficulty. The particles of bodies, indeed, are a great deal too minute for us to difcover their figure by actual infpection; but the phenomena of cryftallization fhew us that this difference actually exifts.

The cryftals of every body affume a peculiar figure. Now as thefe cryftals are all formed in the fame manner, and by the fame law, it is impoffible to conceive any other reafon for their variety but the difference in the form of the particles which compofe them.

But why does one body difplace another? When a particle of barytes is brought within a certain diftance of a particle of fulphuric 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 fuch, relatively to that of the lime, that they cannot approach within a fmall enough diftance 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 furrounding bodies for either.

566 Confequently it ought to be confidered as the *fame*.

Having thus feen that none of the phenomena of *affinity* are inconfiftent with their refulting from the forces which bring about the phenomena of gravitation, we have a right to conclude, that it is at leaft highly probable, that all the motions of the corporeal world are produced by the fame power which, though not effential to matter, was impreffed upon every atom of it by the Great Creator when he formed this univerfe; and that as the effects of this power are modified according to the fituation of the bodies on which it acts, they are known by the different names of *gravity*, *adhefion*, *cohefion*, and *affinity*.

Gravity is the attraction between bodies fo diftant, that the maffes alone influence the refult, and that the power may be confidered as placed in the centre of the attracting bodies.

Adhesion fuppofes a diftance too fmall for our fenfes. It has been demonftrated 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 fame nature. Thefe, inftead of touching only in one fuperficies, as in adhefion, touch in every point where their figure will allow contact: confequently the force of cohefion alfo muft depend upon the figure of the particles.

Affinity unites bodies of a different nature, not merely by one fuperficies, as *adhefion* does, but particle to particle, like *cohefion*; and the moft perfect contact is formed that the figure of the particles will admit. Therefore, in this cafe alfo, the intenfity depends upon the figure of the particles.

567 Saturation explained.

3. If we make the attempt, we fhall find that water will not diffolve any quantity of common falt that we pleafe. Water which refufes to take up any more is faid to be *faturated* with falt. Neither can we combine *any* quantity of potafs with a given portion of fulphuric acid: we may add as much of it as we pleafe, indeed; but if we evaporate the liquid, in order to obtain the falt in cryftals, we fhall find that only *part* of the potafs has united with the acid, and that the reft has cryftallized feparately. From thefe examples, it muft appear evident, that bodies combine with one another by affinity only in certain proportions; or, which is the fame 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 fuppofe, for inftance, that the particles of fulphuric acid are tetrahedrons, and that the particles of potafs are of fuch a form, that one of them can attach itfelf to each of the fides of the acid particle: In that cafe an integrant particle of fulphat of potafs would be compofed of five particles, one of acid and four of alkali; for it is evident, that juft four particles of potafs would combine with every particle of acid, and that the acid would then be faturated, or, which is the fame thing, would be incapable of receiving any more alkaline particles into combination with it. Let us fuppofe now, that there is juft as much potafs as faturates the acid; if more acid be poured in, it cannot enter into combination with the potafs, becaufe all the potafs is already combined with acid.

Thus it appears evident, from the nature of affinity, that the ingredients in every combination muft mutually *faturate* each other, and that no more of either can be

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tional to PM; then let P move towards A, fo as to come to the fituation 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 cafe of the attraction of bodies for one another, PM is lefs than P′M′; and confequently MM′ does not ever return into itfelf, and therefore it muft go *ad infinitum*, having its arc between AB and AC, to which it approaches as afymptotes, the abfciffa always reprefenting the diftance, and the ordinate the attraction at that diftance. 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; fo that the attraction being changed into cohefion will be infinite, and the bodies infeparable, contrary to univerfal experience; fo that P can never come nearer to A than a given diftance. *Nicholfon'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 potass, 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 potass 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 potass cannot be deprived of it by any of the other particles, otherwise the affinity of some particles of sulphuric acid for potass 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* (B). 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 conclusions, but perfectly consistent with them; and consequently they cannot be admitted as of any force.

* Encyc. Method. i. 560.

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.

568 Of the strength of affinity.

4. Since the affinity of almost every two bodies for each other differs *in strength* from that between every other two, it becomes an important problem *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.

569 Attempts to ascertain it.

If the observations formerly made, in order to shew that

(B) 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 jargonia, 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.

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 parricles 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 atmosphere. 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 potass, 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.

Affinity.

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 *
Zinc, - - - - - - -	204
Copper, - - - - - -	142
Antimony, - - - - - -	126
Iron, - - - - - - -	115
Cobalt, - - - - - - -	8

* *Morveau, Ann de Chim.* xxv. 10.

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

(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 $53\frac{3}{4}$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.

574 And Kirwan.

Mr Kirwan has proposed another method of solving the problem. While he was engaged in his experiments 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	Potass.	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 potass and sulphuric acid is 215, and that between nitric acid and lime 96 *.

* Phil. Trans. 1783.

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.

575 Attempt to remedy the defects of his method;

Bergman long ago established as a principle, under the name of a chemical paradox, that *the stronger any salt was, the less of any other it required for saturation.* 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 potaſs require 78,5 Sulphuric acid,
64 Nitric,
51,5 Muriatic,
42 Carbonic,
100 parts of ſoda - - 177 Sulphuric,
135,5 Nitric,
125 Muriatic,
80 Carbonic.

This propoſition, which has been admirably illuſtrated 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.

* Encyc. Method. Chim. i. 597.

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.

	Bergman.			Wenzel.			Kirwan.		
100 parts of	Sulphuric.	Nitric.	Muriatic.	Sulphuric.	Nitric.	Muriatic.	Sulphuric.	Nitric.	Muriatic.
Barytes	15,4		30,8						
Potaſs	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 potaſs, 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.

* Encyc. Method. Chim. i. 591.
† Chim. Ann. ii. 1785.
‡ Phil. Tranſ. 1784.
§ Ann. de Chim. iv. 65.

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 as under:

Sulphat of potaſs { Acid 100, Potaſs 108,7 }

Sulphat of lime { Acid 100, Lime 80,6 }

Nitrat of potaſs { Acid 100, Potaſs 83,33 }

Nitrat of lime { Acid 100, Lime 34,4. }

Now when ſulphat of potaſs and nitrat of lime are mixed together, a double decompoſition takes place, and ſulphat of lime and nitrat of potaſs are formed. Let theſe two ſalts be mixed together; let the quantity of ſulphat of potaſs 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 potaſs, 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.

† Ann. de Chim. xxv. 295.

The truth of the ſecond propoſition may be judged of by the following Tables:

According to Bergman.

100 parts of	Baryt.	Potass.	Soda.	Lime.	Magn.	Amm.	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.	Potass.	Soda.	Lime.	Magn.	Amm.	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.	Potass.	Soda.	Lime.	Magn.	Amm.	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 propofition except the numbers which correfpond to fulphat of foda, fulphat of alumina, nitrat of lime, and muriat of foda, which the late experiments of Mr Kirwan have fufficiently fhewn to be inaccurate.

Wenzel's table correfponds exactly, except the columns under ammonia and alumina, which Morveau has proved to be inaccurate.

Kirwan's table correfponds exactly, except with regard to the quantity of ammonia neceffary to faturate muriatic acid, which does not appear to have been accurately determined by experiment.

Let us therefore take the truth of thefe two propofitions for granted, and let us confider every deviation from them as an error; and let us fee whether they will enable us to difcover the abfolute affinity of fulphuric, nitric, and muriatic acids, for their refpective bafes.

Table I. *Quantity of Bafe neceffary to Saturate* 100 *Parts of the three Acids.*

100 parts	Baryt.	Potass.	Soda.	Lime.	Magn.	Amm.
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 neceffary to Saturate* 100 *Parts of the fix Bafes.*

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
Magnefia	176,2	159,25	105,4
Ammonia	202,6	182,4	127,25

The firft of thefe tables reprefents the affinity between the fame acid and its various bafes; and the fecond that of the bafes for the different acids. If it were required to know the ratios of the affinity which different bafes have for any particular acid, the firft table, fuppofing 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 bafes, we would find them in the fecond table.

576 And to conftruct tables of affinity.

But if we wifhed to know what was the affinity between one acid and bafe, compared with that between another acid and a different bafe; or if we wanted to have not the relative but the abfolute affinity between two bodies—it is plain that we could not find it in either of the tables; for the abfolute affinity muft confift of two things, the affinity which the acid has for the bafe, and the affinity which the bafe has for the acid. Now the firft table gives us the one of thefe, and the fecond the other; fo that in order to reprefent affinity in abfolute numbers, the two tables muft be multiplied into one another. This was the miftake into which Mr Kirwan fell. His method confifted merely in conftructing a table like our firft, which (fuppofing the numbers accurate) gave only the affinity between the bafes and the fame acid, but left out the affinity between the different acids and the fame bafe; confequently the different columns could not be compared with each other.

It is evident, however, that if the tables were multiplied together in their prefent ftate, they could not poffibly give an accurate table of affinities. For that purpofe, it is neceffary to put the fame number in the firft column of each table, and then to fubftitute other numbers in the remaining columns, having the fame 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 fix Bafes for three Acids.*

	Barytes.	Potass.	Soda.	Lime.	Magn.	Amm.
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

Table

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
Magnefia	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
Magnefia	2434	2193	1786
Ammonia	2112	1763	1515

On the fuppofition that the two propofitions mentioned above were ftrictly true, and that the numbers which we fixed upon were precifely the quantities of acid and bafe neceffary to faturate each other reciprocally, this laft table would reprefent accurately in numbers the ftrength of the affinities of the three acids for each of the fix bafes refpectively.

We muft acknowledge, however, that the truth of thefe propofitions has not hitherto by any means been fufficiently proved; but a great number of facts concur to render them exceedingly probable, and highly worthy of the attention of chemical philofophers. And we hope that the method propofed by Morveau, and which had been previoufly practifed by Richter, of verifying theoretical calculations of the compofition of the falts, by mixing together two falts which mutually decompofe each other, and afcertaining whether the refult correfponds with calculation, will be followed out, and that it will be the means of enfuring more accuracy than it has hitherto been poffible to obtain.

No one will fufpect that any thing which has here been faid is meant as a reflection on the ingenious chemifts who have attempted to folve this moft difficult of all chemical problems, the proportion of the ingredients which enter into the compofition of the falts. Mr Kirwan, in particular, is entitled to the greateft praife for the perfevering induftry with which he has profecuted the fubject, for the candour which he has difplayed, and for the new rout which he has opened to the chemical philofopher. Though this problem has not hitherto been folved, and though the difficulties which furround it are almoft infurmountable, we may hope much from the general fenfe which is at prefent entertained of its importance, and from the zeal and abilities of thofe philofophers who have particularly turned their attention to it.

577 Morveau's table of affinity.

In the mean time, the following Table of the ftrength of affinities by Morveau, though the numbers be arbitrary, will be found of very great ufe *.

	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
Magnefia	50	40	22	17	6
Alumina	40	36	18	15	2 (D)

5. Although every chemical combination is produced by the fame general law, yet as their phenomena vary fomewhat according to circumftances, affinities have, for the fake of greater perfpicuity, been divided into claffes. Thefe claffes may be reduced to *three*—*fimple*, *compound*, and *difpofing* affinities. 578 Three claffes of affinity,

The *firft clafs* comprehends all thofe cafes in which only *two bodies combine* together; as, for inftance, fulphuric acid and potafs, oxygen and carbon. The affinities which belong to this clafs are known by the name of *fimple* or *fingle affinities*. Although one of the fubftances to be combined happens to be already united with another body, the combination is ftill reckoned a cafe of fingle affinity. Thus fuppofe the fulphuric acid previoufly combined with magnefia, and forming with it the falt called *fulphat of magnefia*, as foon as potafs is prefented, 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 fingle affinity. Thus, when fome potafs is dropped into tartarous acid, part of the acid unites with the alkali, and forms tartrite of potafs; after this the remainder of the acid combines with the tartrite juft formed, and compofes a new falt known by the name of *acidulous tartrite of potafs*, or *tartar*. This is evidently nothing elfe than two inftances of fimple affinity immediately following each other. 579 Viz. fimple affinity,

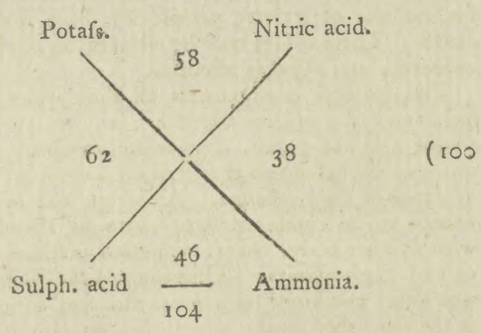
When more than three bodies are mixed, decompofitions and new combinations often take place, which could 580 Compound affinity,

* *Encyc. Method. Chim.* i. 773.

(D) This table, however, does not correfpond quite accurately to all the phenomena. For inftance, according to it, fulphat of barytes is not decompofed by carbonat of foda, although the contrary takes place in fact.

Affinity.

could not have been produced had the bodies been presented in a different ſtate. If, for inſtance, into a ſolution of ſulphat of potaſs there be poured nitric acid, no decompoſition is produced, becauſe the ſulphuric acid has a ſtronger affinity for potaſs 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 potaſs*, 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 potaſs and ſulphuric acid be = 62; that between nitric acid and ammonia = 38 ; that between the ſame acid and potaſs = 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,



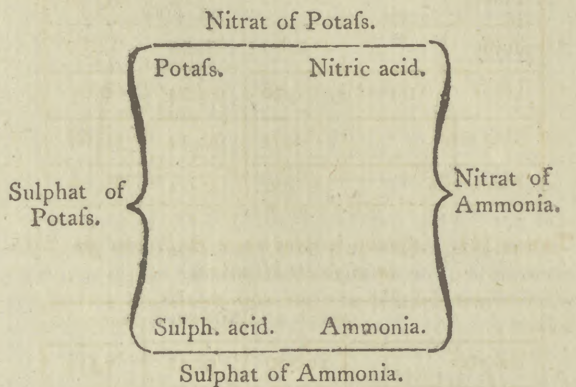
It is evident, that as 58 and 46 = 104, are greater than 62 + 38 = 100, they would overcome the other forces and ſhut the cylinders. Juſt ſo the affinity between potaſs and nitric acid, together with that between ſulphuric acid and ammonia, overcomes the affinity between potaſs and ſulphuric acid, and 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 ; 1*ſt*, 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 potaſs 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 potaſs and nitric acid, and that between ſulphuric acid and ammonia, are divellent affinities ; and as they are in this caſe ſtrongeſt, they actually deſtroy the former combinations and form new ones.

Affinity.

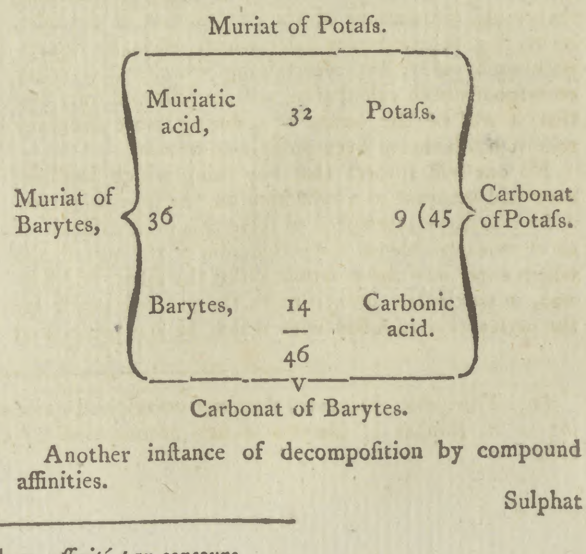
Bergman, who publiſhed a great many caſes of compound affinities, employed to explain them a method ſomewhat different from this. He would have repreſented the above caſe in the following manner :



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 potaſs = 32 ; the affinity between potaſs 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 potaſs 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.*

		Sulphat of Lime.		
	Sulph. acid,	54	Lime.	
Sulphat of Ammonia,	46		44 (90	Nitrat of Lime.
	Ammonia,	38 — 92	Nitric acid.	
		Nitrat of Ammonia.		

Suppoſing Morveau's numbers exact, it follows alſo, even prior to experiment, that no decompoſition takes place when ſulphat of lime and muriat of potaſs are mixed;

	Sulphuric acid,	62	Potaſs.	
Sulphat of Lime,	54		32 (86	Muriat of Potaſs.
	Lime,	20 — 82	Muriatic acid.	

for the quieſcent affinities are 86, and the divellent only 82.

Nor when acetite of lime and muriat of ſoda are mixed;

	Acetous acid,	25	Soda.	
Acetite of Lime,	19		28 (47	Muriat of Soda.
	Lime,	20 — 45	Muriatic acid.	

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*.

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.

		Sulphat of Magneſia.		
	Sulphuric acid,	50	Magneſia.	
Sulphat of ſoda,	58		40 (98	Nitrat of magneſia.
	Soda,	50 — 100	Nitric acid.	
		Nitrat of Soda.		

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:

		Sulphat of Potaſs.		
	Sulph. acid,	62	Potaſs.	
Sulphat of Barytes,	65		9 (74	Carbonat of Potaſs.
	Barytes,	14 — 76	Carbonic acid.	
		Carbonat of Barytes.		

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 : ——⌐——¬.

581 And diſpoſing affinity.

The third claſs of affinities has been called by Mr Morveau *diſpoſing affinities*, becauſe they *diſpoſe* 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 potaſs, and it unites with oxygen with avidity. Its previous union with potaſs, 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

* *Encyc. Method. Chim.* i. 556.

Affinity.

of the sulphur with oxygen. This is done in some measure by the potass. 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*.

* *Proust* and *Morveau*, *Encyc. Method. Chim.* i. 474.

† *Morveau*, *ibid.*

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

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 attraction 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, happen 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.

* *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 be - - -	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.

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 ſubtile 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.

When ſulphur and arſenic acid are expoſed to heat, ſulphuret of arſenic is formed * evidently by a kind of compound affinity.

* *Pelletier.*

Oxygen Gas.

Caloric	12	Oxygen	
	60		Arſenic Acid.
Sulphur	50	Arſenic	

Sulphuret of Arſenic.

In the ſame manner, when nitrat of potaſs and boracic acid are expoſed to heat, the nitric acid is volatilized, and borat of potaſs is left behind.

Nitric Acid in Vapour.

Caloric	4	Nitric acid	
	58		Nitrat of Potaſs.
Boracic acid	55	Potaſs	

Borat of Potaſs.

By the ſame compound affinity boracic acid and heat decompoſes muriat of ſoda.

Muriatic Acid Gas.

Caloric	10	Muriatic acid	
	31		Muriat of Soda.
Boracic acid	24	Soda	

Borat 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 *.

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 †.

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 ‡.

* *Weſtrum, Ann. de Chim.* ii. 118.

† *Scheele* and *Gren, Ann. de Chim.* xxiii.

‡ *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.

585 Of Count Rumford's opinion reſpecting affinity.

From the important part which caloric acts in chemical combinations, Count Rumford has been lately induced to ſuſpect that this ſubtile 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 allow; 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,
Hydroſulphurets.

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* (*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 586 Common hard ſoap.

 and

(G) *Beckmann's Hiſtory of Inventions*, III. 239.—A ſimilar word is ſtill uſed by the common people of Scotland.

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and aſhes; and that the German ſoap was reckoned the beſt *.

* *Pliny*, lib. xviii. c. 51.

587 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.

588 Its ſophiſtication.

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.

* *Ann. de Chim.* xix. 336.

589 Proportion of its ingredients.

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.

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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 potass.—Potass 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 potass 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 potass: 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 potass. 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 potass, but soda: for when the common salt (muriat of soda) is added, the potass 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 potass 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.

* *Thouvenel.*

5. Soap of magnesia.—This soap may be formed by mixing together solutions of common soap and sulphat of magnesia. 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.*

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 ||. 596 Of mercury,

|| *Ibid.*

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 ¶. 597 Of zinc,

¶ *Ibid.*

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. 598 Of cobalt,

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,

* *Ibid.*

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 †. 600 Of tin,

† *Ibid.*

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 ‡. 601 Of iron,

‡ *Ibid.*

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 §. 602 Of copper,

§ *Ibid.*

14. Soap of lead.—It may be formed by means of acetite 603 Of lead,

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(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*.

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 †.

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 ‡.

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 §.

We owe the following resinous soaps to Mr Mezaize.

607 Soap of turpentine and potass. 18. Soap of turpentine and potass.—576 grains of turpentine were dissolved in 9216 grains of alcohol, and then 576 grains of potass 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 potass dissolved in water. This soap was put in a vessel for six weeks; during which time 72 grains of solution of potass 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 potass.—By treating 9216 grains of alcohol, 1728 grains of benzoin, and 576 grains of potass, 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 potass—1152 grains of balm, 2304 grains of potass, and 9216 grains of alcohol, produced a soap of a reddish colour, and pretty consistent.

610 Of guaiac, 21. Soap of guaiac and potass.—1728 grains of guaiac was dissolved in 18648 grains of alcohol, and the solution filtered, and to this 1728 grains of potass 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 disagreable taste. It dissolved in alcohol, and formed a green tincture. Vinegar decomposed it.

611 And of scammony. 22. Soap of scammony and potass.—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 disagreable taste. Its solution in alcohol is of a deep amber colour ‖.

* Berthollet, ibid.

† Ibid.

‡ Ibid.

§ Ibid.

‖ Jour. de Phys. xv. 441.

Sect. II. *Of Acid Soaps.*

612 Method of forming 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.

Acid Soaps.

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. Potass decomposes it, forming sulphat of potass. 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. 613 Acid soap of lintseed oil,

2. Soap of sulphuric acid and oil of almonds.—Soluble in water; solution milky. Frothes. Soluble in alcohol; solution brown and transparent. Potass, lime, nitric acid, muriatic acid, sulphurous acid (the oil separated assumed the consistence of turpentine), tartar, acidulous oxalat of potass, 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. 614 Of almond 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. Potass, ammonia, magnesia, nitric acid, muriatic acid, vinegar, nitre, sal ammoniac, acetite of lead and white oxide of lead, decompose it. 615 Of olive oil,

4. Soap of sulphuric acid and butter of cocao.—It is hard, and marbled like Venice soap. Solution in water grey, opaque, viscid; frothes. Solution in alcohol yellow and transparent. Potass, ammonia, nitric, muriatic, and acetous acids, tartar, sal ammoniac, tartrite of potass, 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. 616 Of butter of cocao,

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. Potass, ammonia, nitric and muriatic acids, decompose it. 617 Of wax,

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. 618 Of spermaceti,

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, 619 Of oil of eggs,

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 acetous acid, boracic acid, tartrite of potass, 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.

Mr Achard, to whom we owe these soaps*, could not succeed in his attempts to form soaps with nitric and muriatic acids.

* Journ. de Phys. xvi. 409.

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 potass is called *sulphat of potass*.

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.

Sulphats.

Sect. I. *Of Sulphats.*

Sulphuric acid is capable of combining with all the alkalies, with alkaline earths, alumina, jargonia, and the greater number of the metallic oxides. The principal neutral salts which it forms are as follows:

1. Sulphat of potass.—This salt may be formed by saturating diluted potass 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*, *arcanum duplicatum*, *panacea holsatica*, *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 potass*, when they formed their new nomenclature in 1787 (K). 624 Sulphat of potass.

When the solution of sulphat of potass 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 Its properties.

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 potass*.

(L) This is called *decrepitation*.

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 ‖.

* Kirwan. † Id. ‡ Bergman. § Id. ‖ Fuchs, Ann. de Chim. vi. 29.

It is sometimes luminous in the dark, as Mr Giobert has observed ¶.

¶ Ann. de Chim. x. 40.

626 Sulphat of soda.

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 *.

* Irish Trans. iv.

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,	——— potass,
Muriat of potass,	——— lime,
——— soda,	Carbonat of barytes,
——— magnesia,	——— potass.
——— lime †,	

† Scheele.

627 Sulphat of ammonia.

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 *.

* Irish Trans. ibid.

When exposed to the air, it slowly attracts moisture.

When heated, it first decrepitates, then melts, and in close vessels sublimes, but with some loss of its alkali †.

† Kirwan's Mineral. ii. [illegible]

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 potass,	——— magnesia,
——— soda,	Carbonat of potass,
——— barytes,	——— soda,
——— lime,	——— barytes,
——— magnesia,	——— lime,
——— mercury*,	——— magnesia,
Acetite of potass,	Phosphat of lime †.

* Bergman. † Delkeskamp Ann. de Chim. vi. 37.

628 Sulphat of barytes.

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.

It is soluble in 43,000 times its weight of water at the temperature of the atmosphere ‖.

‖ Kirwan's Min. i. 136.

Sulphuric acid dissolves it when concentrated and boiling, but it is precipitated by the addition of water.

When exposed to heat it melts, and, if the heat be very strong, gradually dissipates.

629 Bologna stone.

After being heated red hot, it has the property of being luminous in the dark. This was first observed 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 potass,
——— ammonia,	——— soda *.

‖ Afzwelius.

630 Sulphat of lime.

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

(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.

Sulphats. 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 it *.

* Macquer.

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 potass,
——— potass,	——— soda,
Carbonat of barytes,	——— magnesia?
	——— alumina †.

† Bergman.

632 Sulphat of strontites.

6. Sulphat of strontites. 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, Transf. Edin. iv. 10.

633 Sulphat of magnesia.

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 ¾ths of its weight of boiling water. The volume of water is increased ¼th 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 evaporated, but it cannot be decomposed by means of 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 potass,	Acetite of lime,
——— soda (P),	Carbonat of barytes,
——— lime,	——— potass,
Acetite of barytes,	——— soda *,
——— potass,	——— ammonia (Q).

* Bergman.

634 Sulphat of ammonia and magnesia.

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 †.

† Ann. de Chim. iv. 211.

635 Sulphat of alumina.

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 §.

‡ Vauquelin, Ann. de Chim. xxii. 277. and Chaptal, ibid. 294.

§ Ibid. p. 277.

636 Alum.

10. Sulphat of alumina and potass, or alum. The στυπτηρια 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.

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 Chalomer.

The alum of commerce is usually obtained from earths containing sulphur and clay, or sulphuric acid and clay.

637 Its composition,

The composition of alum has been but lately understood

(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.

stood 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 incontestibly that alumina is another ingredient. But sulphuric acid and alumina are incapable of forming alum: Manufacturers knew, that the addition of a quantity of potass, 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 potass. Various conjectures were made about the part which potass 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 potass 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.

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 parts of boiling-water dissolve 100 of alum ‡.

* Neumann and Chaptal.
† Kirwan and Chaptal.
‡ Bergman.

A hundred parts of alum contain, according to Kirwan, 17,62 parts of acid, 18 of earth (and alkali), and 64,38 of water §.

§ Kirwan's Min. ii. 14.

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 potass,
—— lime,	—— —— soda,
—— ammonia,	—— —— lime,
—— magnesia,	—— —— ammonia,
Muriat of barytes,	—— —— magnesia,
—— —— potass,	Carbonat of barytes,
—— —— soda,	—— —— potass,
—— —— lime,	—— —— soda,
—— —— ammonia,	—— —— lime,
—— —— magnesia,	—— —— ammonia,
Acetite of barytes,	—— —— magnesia.

639 Homberg's pyrophorus.

If three parts of alum and one of flour or sugar be 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 (T), a substance is obtained known by the name of *Homberg'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 Homberg 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 potass was incapable of forming pyrophorus, and that sulphat of potass 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 Dict.
† Scheele on Fire, and on Pyrophorus.

These facts have thrown a great deal of light on the nature of Homberg'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 potass, 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 ‡.

‡ Ann. de Chim. xxii. 293.

11. Sulphat

(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*.

(T) Care must be taken not to keep it too long exposed to the heat.

640 Sulphat of jargonia.

11. Sulphat of jargonia (υ). 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 hydrosulphuret (τ) of jargonia *.

Klaproth informs us, that with excess of acid sulphat of jargonia forms transparent stelliform crystals, soluble in water, and having an astringent taste †.

* *Vauquelin, Ann. de Chim.* xxii. 199.

† *Jour. de Phys.* xxxvi. 187.

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.

641 Green sulphat of iron.

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*, *calchantum* ‡. It was formerly called *green vitriol*.

‡ *Lib.* xxxiv. c. 12.

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 parallelopipeds.

It has a sharp astringent taste.

It is soluble in six times its weight of water at the temperature of 60°, and in $\frac{3}{4}$ths of its weight of boiling water §.

§ *Bergman.*

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 (υ) of oxide, and 46 of water.

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*.

642 Red sulphat of iron.

Little is known of its properties, except that it is deliquescent, incrystallizable, and soluble in alcohol.

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.

643 Sulphat of zinc.

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 ascribe

(υ) *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 silica,
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 silica, 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.

(υ) 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.

Its cryſtals are oblique parallelopipeds; they are of a white colour, and very bitter §.

§ *Scheele*,

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.

18. Sulphat of tin.—Nothing is known concerning this ſalt, except that it cryſtallizes in fine needles interlaced with one another *.

* *Monnet.*

648 Sulphat of copper.

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 temperature of 60°; but in a much ſmaller quantity of boiling water *.

* *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. 23.

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. 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. 652 White ſulphat of mercury.

‡ *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 §.

§ *Fourcroy, ibid.*

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* ‖. 653 Yellow ſulphat of mercury.

‖ *Fourcroy, ibid.*

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 is 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 *.

This triple ſalt may be formed alſo by pouring ammonia upon acidulous ſulphat of mercury, or on yellow ſulphat of mercury †.

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.

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 M'Gregor. 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 §.

* Fourcroy, ibid.

† Ibid.

‡ Bergman.

§ Klaproth, Philoſophical Mag. i. 80.

Sect. II. *Of Sulphites.*

Salts compoſed of ſulphurous acid united reſpectively with alkalies, 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 carbonat of potaſs till all effervеſcence ceaſes. The ſolution becomes hot, and cryſtallizes by cooling ‖.

Its cryſtals are white and tranſparent; their figure that of rhomboidal plates. Its cryſtallization often preſents ſmall needles diverging from a common centre ¶.

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.

‖ Fourcroy, and Vauquelin, Nicholſon's Journ. i. 317.

¶ Ibid.

Sulphites. When expoſed to the air, it effloreſces, becomes opaque and hard, and is gradually converted into *ſulphat of potaſs* by abſorbing oxygen.

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 mangaueſe, 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 carbonat;

All metallic ſalts except carbonats;

All neutral ſalts whoſe acid has a ſtronger affinity for potaſs than ſulphurous acid has *.

2. Sulphite of ſoda.—This ſalt was firſt accurately deſcribed by Fourcroy and Vauquelin. 660 Sulphite of ſoda.

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 carbonat of potaſs, and the other ſalts which decompoſe ſulphite of potaſs †.

3. Sulphite of ammonia.—This ſalt was firſt deſcribed by Fourcroy and Vauquelin ‡. 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 §.

4. Sulphite of barytes.—This ſalt was firſt deſcribed by Berthollet ‖. 662 Sulphite of barytes.

It is incryſtallizable; it has no perceptible taſte; and is perfectly inſoluble in water ¶.

* Ibid.

† Ibid.

‡ Fourcroy and Vauquelin, Nicholſon's Journ. i. 317.

§ Ibid.

‖ Ann. de Chim. ii 57.

¶ Fourcroy and Vauquelin.

It

Sulphites

It is compoſed of 59 parts of barytes, 39 parts of acid, and 2 of water.

It does not eaſily change into a ſulphat by expoſure to air; but heat produces this effect *.

* Ibid.

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.

665 Sulphite of alumina.

7. Sulphite of alumina.—Firſt formed by Berthollet.

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.

Heat decompoſes it ¶.

¶ Fourcroy and Vauquelin.

666 Sulphite of iron.

8. Sulphite of iron.—It was firſt formed by Berthollet.

Its cryſtals are white, and have but very little of the ſtyptic taſte of iron ſalts *.

Berthollet alſo formed the ſulphites of zinc and tin, but he has not deſcribed them.

* Ann. de Chim. ii. 58.

Sect. III. *Of Nitrats.*

Those ſalts, in the compoſition of which the nitric acid forms one ingredient, are called *nitrats*.

667 Nitre.

1. Nitrat of potaſs, 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 potaſs, 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 Reproduction of nitre.

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.

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 potaſs, 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.

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 potass is equally extraordinary. If any thing can give countenance to the hypothesis, that potass is composed of lime and azot, it is this singular fact.

669 Nitrat of soda.

2. Nitrat of soda. 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 soda, 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,
——— potass,	Acetite of barytes,
——— alumina,	——— potass,
Muriat of barytes,	Carbonat of barytes,
——— potass,	——— potass.
——— 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,
——— potass,	——— potass,
——— alumina,	——— soda,
Acetite of lime	Muriat of lime,
——— magnesia,	——— magnesia,
——— alumina,	——— alumina,
Muriat of barytes,	Carbonat of barytes,
——— potass,	——— potass,
——— soda,	——— soda.

671 Nitrat of barytes.

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.

672 Nitrat of lime.

5. Nitrat of lime. This salt forms by crystallization six-sided prisms, terminated by dehedral 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. 29.

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 potass,
——— potass,	Carbonat of barytes,
——— soda,	——— potass,
——— ammonia,	——— soda,
——— alumina,	——— ammonia,
Muriat of barytes,	——— alumina,
——— potass,	——— magnesia,
Acetite of barytes,	Tungstat of ammonia §.

§ Scheele.

673 Nitrat of strontites.

6. Nitrat of strontites. 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.

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.

674 Nitrat of magnesia.

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 $\frac{1}{9}$th of its own weight of it ¶.

¶ Bergman, ii. 381.

One hundred parts of magnesia require 255 of nitric acid for saturation *.

* Kirwan.

It deliquesces in the air, according to Bergman; but Dijonval affirms, that he has procured it in crystals which rather effloresce.

It

Nitrats.

It is decomposed by heat.

By compound affinity it is decomposed by

Sulphat of barytes,	Muriat of lime,
——— potass,	Acetite of barytes,
——— soda,	——— potass,
——— ammonia,	——— soda,
——— alumina,	——— lime,
Muriat of barytes,	Carbonat of barytes,
——— potass,	——— potass,
——— soda,	——— lime.

675 Nitrat of ammonia and magnesia.

8. Nitrat of ammonia and magnesia. This triple salt was discovered by Mr Fourcroy. Into a saturated solution of nitrat 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 nitrat; and that the quantity of nitric acid necessary to saturate 21 grains of magnesia, when saturated with ammonia, produced 84 grains of nitrat of ammonia. He concludes, therefore, though the data are not quite satisfactory, that the triple salt is composed of 288 grains of nitrat of magnesia, and 84 of nitrat of ammonia *.

* *Ann. de Chim.* iv. 215.

676 Nitrat of alumina.

9. Nitrat of alumina. This seems to have been first attended to by Beaumé.

Its crystals are pyramidal. It has a very astringent taste. It is soluble in water, and deliquesces in the air.

677 Nitrat of jargonia.

10. Nitrat of jargonia. This salt may be easily formed by pouring nitric acid on newly precipitated jargonia.

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 jargonia 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 jargonia 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 nitrat of jargonia 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.* xxii. 199.

678 Nitrat of iron.

11. Nitrat 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 Nitrat of zinc.

12. Nitrat of zinc. The oxide of zinc combines with nitric acid, and forms with it a salt which crystallizes in compressed and striated 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 *.

* *Fourcroy.*

680 Nitrat of manganese.

13. Nitrat 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 †.

† *Scheele on Manganese.*

681 Nitrat of cobalt.

14. Nitrat 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.

682 Of nickel.

15. Nitrat 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 ‡.

‡ *Bergman,* ii. 268.

683 Of lead.

16. Nitrat 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 potass,
——— soda,
——— ammonia,
Carbonat of soda §.

§ *Bergman.*

684 Of tin.

17. Nitrat of tin. Tin is converted into an acid by nitric acid: it is not probable, therefore, that any permanent nitrat of tin can be formed.

685 Of copper.

18. Nitrat 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° ‖.

‖ *Sage.*

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.

686 Of bismuth.

19. Nitrat 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.

687 Of antimony.

20. Nitrat of antimony. Little is known concerning this salt, except that it is very deliquescent, and is decomposed by heat.

688 Of arsenic.

21. Nitrat of arsenic. With white oxide of arsenic nitric acid forms a salt which crystallizes. It is very deliquescent. It does not detonate.

689 Of mercury.

22. Nitrat 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 soda,
Borax.

690 Of ammonia and of mercury.

23. Nitrat of ammonia and mercury. This triple salt may be formed by pouring ammonia into a solution of

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.

691 Nitrat of silver,

24. Nitrat of silver. This salt may be formed by dissolving silver in nitric acid.

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 ¾ths of an inch in length and ¼th in breadth †.

† *Klaproth, Journ. de Phys.* xxxvii. 158

693 Titanium,

26. Nitrat of titanium. It is capable of crystallizing.

694 Tellurium.

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. 80.

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 potass.

1. Muriat of potass. This salt was formerly called *febrifuge* or *digestive salt of Sylvius*, and *regenerated sea salt*.

Its crystals are cubes, but rather irregular.

It has a disagreeable bitter taste. Its specific gravity is 1,836 §.

§ *Kirwan.*

It is soluble in three times its weight of water at the temperature of 60°, and in double its weight of boiling water ‖.

‖ *Bergman.*

It is composed, according to Bergman, of 31 parts of acid, 61 of potass, 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 soda,	Nitrat of ammonia,
—— ammonia,	—— magnesia,
—— alumina,	—— alumina,
Nitrat of soda,	—— lead.
—— lime,	

696 Muriat of soda.

2. Muriat of soda, common or sea salt. This salt has been known, and in common use, from the earliest ages. It is sometimes called also *sal gem*.

Its crystals are cubes, but they often assume other forms. Its specific gravity is 2,120 *.

* *Kirwan.*

Its taste is universally known, and is what is strictly speaking denominated *salt*.

It is soluble in $2\frac{14}{17}$ times its weight of water at the temperature of 60°, and in $2\frac{13}{17}$ 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 soda 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,
—— potass *,	Pyrolignite of barytes ‖,
—— iron †,	—— lead ‖,
Nitrat of ammonia,	Carbonat of potass (*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. 297.
(*c*) *Scheele.*

697 How decomposed by red oxide of lead.

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 soda. 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 soda has, and ought therefore to decompose it.

* *Ann. de Chim.* xiv. 15.

698 Muriat of ammonia.

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 †.

† *Pliny*, lib. xxxi. c. 7. See *Sal Ammoniac*, Encyc.

It assumes the form of plumose crystals. The individual crystals are long hexahedral pyramids. Its specific gravity is 1,420 ‡.

‡ *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 §.

§ *Kirwan's Mineral.* ii. 34.

In its common form (which is an opaque mass) it is not affected by the air, but its crystals are liable to deliquesce.

Heat

Muriats.

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,
——— potass,	——— potass,
——— 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,

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 ‡.

‡ Ann. de Chim. iv. 8.

701 Muriat of lime,

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.

It very speedily deliquesces when exposed to the air. By heat it melts into a very hard vitreform substance.

The following salts decompose it by compound affinity :

Sulphat of soda,	Carbonat of potass,
——— ammonia,	——— soda,
——— magnesia,	——— ammonia *,
——— alumina,	——— barytes,
Nitrat of soda,	——— magnesia,
——— ammonia,	——— alumina,
——— magnesia,	Acetite of barytes,
——— alumina,	——— potass,
	——— soda.

* Bergman.

702 Muriat of strontites,

7. Muriat of strontites. 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 †.

† Hope, Trans. Edin. iv. 12.

703 Muriat of magnesia,

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 ‡.

‡ Bergman, ii 383.

It has a very bitter taste. It is soluble in its own weight of water §, and in five parts of alcohol ‖.

§ Fourcroy.

‖ Bergman, ii. 383.

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 ¶.

¶ Bergman, ibid.

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 *.

* Irish Trans. iv.

It deliquesces very speedily when exposed to the air.

A strong heat decomposes it. When dried in a high temperature, it is very caustic †.

† Westrum, Ann. de Chim. ii. 135.

The following substances decompose it by compound affinity :

Sulphat of soda,	Acetite of potass,
——— ammonia,	——— soda,
——— alumina,	——— silver ‡.
Nitrat of ammonia,	

‡ Bergman.

Carbonat

(Y) Only at the common temperature. At a high temperature carbonat of ammonia decomposes muriat of magnesia. See *Westrum, 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 Pissis has observed, that it does not decompose sulphat of lime nor of potass. See *Ann. de Chim.* xv. 317.

Muriats.

Carbonat of barytes,	Carbonat of ſoda
——— potaſs,	——— ammonia (Y).

704 Muriat of ammonia and magneſia, 9. 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, 10. 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,
——— potaſs,	——— potaſs,
——— ſoda,	——— ſoda,
——— lime,	——— ammonia.

706 Muriat of jargonia, 11. Muriat of jargonia.—This ſalt is eaſily formed by pouring muriatic acid on newly precipitated jargonia. It is colourleſs; its taſte is very aſtringent: by evaporation it furniſhes ſmall tranſparent cryſtals in needles, which loſe their tranſparence in the air. Muriat of jargonia 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 jargonia 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 jargonia 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 jargonia inſoluble compounds that precipitate in white flakes.

The gallic acid poured into muriat of jargonia produces a white precipitate; but a green, bordering on grey, if the jargonia 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 jargonia than muriatic acid has; and that the gallats of jargonia and iron are ſoluble in muriatic acid.

Carbonat of potaſs decompoſes muriat of jargonia, 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 jargonia, occaſions a ſlight efferveſcence; the liquor becomes milky, and in a few days becomes a white ſemitranſparent jelly.

Alumina decompoſes muriat of jargonia 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 jargonia is quite pure. Here, then, is a method of freeing jargonia from iron *.

* *Vauquelin, Ann. de Chim.* xxii. 201.

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 ſalt. 707 Muriat of iron,

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. 708 Muriat of zinc,

14. Muriat of mangaueſe.—Muriatic acid diſſolves the white oxide of manganeſe. Its ſolution affords by evaporation angular ſhining cryſtals †: They are deliqueſcent and ſoluble in alcohol ‡. 709 Muriat of manganeſe,

† *Scheele* on *Manganeſe.*
‡ *Kirwan's Mineral.* ii. 37.

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. 710 Cobalt,

16. Muriat of nickel.—This ſalt is deliqueſcent, and loſes its acid when expoſed to the air §. 711 Nickel,

§ *Bergman*, ii. 268.

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. 712 Lead,

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.

|| *Bergman.*

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. 713 Tin,

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,

(Y) 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.

714 Muriat of copper,

19. Muriat of copper.—This ſalt may be formed by diſſolving copper or its oxide in muriatic acid.

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. It is decompoſed by nitrat of ſilver †.

† Bergman.

715 Muriat of biſmuth,

20. Muriat of biſmuth.—This ſalt cryſtallizes with difficulty. By ſublimation it forms a ſoft fuſible ſubſtance, formerly called *butter of biſmuth*.

716 Antimony,

21. Muriat of antimony.—This ſalt is found native. It cryſtallizes in priſms. When heated it evaporates.

717 Arſenic,

22. Muriat of arſenic.—This ſalt cryſtallizes; it is very volatile, and not very ſoluble, in water ‡.

‡ Bergman, ii. 293.

718 Mercury,

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.

It is decompoſed by ſulphat of ammonia §.

§ Bergman.

719 Muriat of ammonia and mercury,

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.

Sulphuric, nitric, and muriatic acids decompoſe it ‖.

‖ Fourcroy, Ann. de Chim. xiv. 47.

720 Muriat of ſilver,

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 Klaproth.

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.

Oxy-muriats.

722 Oxy-muriat of potaſs,

1. Oxy-muriat of potaſs.—This ſingular ſalt was diſcovered by Mr Berthollet in 1786. It may be formed by ſaturating a ſolution of potaſs with oxy-muriatic acid gas. By evaporating this ſolution in the dark, common muriat of potaſs is firſt obtained: When it is ſeparated, and the liquor allowed to cool, oxy-muriat of potaſs 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 $2\frac{1}{2}$ 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 †.

* Hoyle, Nicholſon's Journal, ii. 292.

† Ibid.

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 Chevraud. 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 Vauquelin 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.

723 Oxy-muriat of ſoda,

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.

724 Oxy-muriat of barytes, lime, magneſia,

4. Oxy-muriat of barytes. }
5. ——————— lime. } Theſe ſalts were diſcovered by Berthollet
6. ——————— magneſia. } alſo. They all poſſeſs

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).

725 Oxy-muriat of mercury,

7. Oxy-muriat of mercury.—This ſalt was formerly called *corroſive ſublimate*, and afterwards *corroſive muriat*

(z) We have been informed, that this ſalt had been uſed by bleachers in Scotland ſome years before Mr Tennant propoſed it.

Oxy-muriat. *of mercury*. Berthollet first pointed out the nature of its composition.

This salt was mentioned by Rhases 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 parallelopipeds, 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 $\frac{3}{8}$ths of its weight of this salt †.

* Spielman.

† Macquer.

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.

‡ Ann. de Chim. i. 1. and xii. 225.

It is decomposed by

Tartar,

Most 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 $\frac{1}{7}$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 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 †.

* Ann. de Chim. i. 3.

† Ann. de Chim. xiii. 225.

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 Oxy-muriat of iron.

9. Oxy-muriat of iron. This salt is deliquescent; colourless; of a pure bitter taste, without any of the sweet astringency of the common salts of iron ‡.

‡ Lambe, Manchester Mem. v. p. 1.

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.*

Phosphats.

THOSE salts, into which phosphoric acid enters as an ingredient, are called *phosphats*. This class of salts was first discovered by Margraf.

728 Phosphat of potass,

1. Phosphat of potass. 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.

729 Phosphat of soda,

2. Phosphat of soda.—Dr Pearson, who first formed this salt, gives the following process for preparing it:

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 *argentum vivum*.

Phosphats. *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, 4. Phosphat of barytes.—This salt is insoluble in water *.

* Morveau.

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 potass ‡,

——— soda §.

† Dellestamp Ann. de Chim. vi. 37.

‡ Bergman.

§ Id.

733 Of strontites, 6. Phosphat of strontites.—This salt was first formed by Dr Hope. It is a white powder soluble in 1920 parts of boiling water ‖.

‖ Dr Hope Trans. Edin. iv. 16.

734 Of magnesia, 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 acetite 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 *.

¶ Bergman, ii. 390.

* Wenzel.

735 Of alumina, 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, 12. Phosphat of nickel.—It is greenish, and does not crystallize §.

§ Bergman, ii. 268.

13. Phosphat of arsenic.—It crystallizes in small grains hardly soluble in water *. Borats. 740 Of arsenic,

* Bergman, ii. 290.

14. Phosphat of uranium.—First formed by Klaproth. It does not crystallize, but assumes the appearance of yellowish white flakes, difficultly soluble in water. 741 Of uranium,

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. 742 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 potass.—This salt, formed by combining boracic acid and potass, is very little known. Baron first formed it. Borat of potass crystallizes, is soluble in water, and may be melted into a vitreous mass, soluble in water. 743 Borat of potass,

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 ropy, 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 ‡.

‡ Accum, Nicholson's Journal, ii. 28.

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.

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. ch. 4.

4. Borat

Borats. 4. Borat of barytes.—Unknown.

5. Borat of lime.—It is difficultly soluble in water, and did not crystallize with Beaumé.
746 Of lime,

747 Of strontites, 6. Borat of strontites.—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 *.

* Hope, Trans. Edin. iv. 17.

748 Of magnesia, 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 †.

† Bergman, ii. 386.

749 Of alumina, 8. Borat of alumina.—It does not crystallize, and is scarcely soluble in water.

750 Of iron, 9. Borat of iron.—Its crystals are of a yellow colour, but the salt has never been examined with attention.

751 Of zinc, 10. Borat of zinc.—This salt does not appear to be capable of crystallizing. By heat, it melts into a light green insoluble slag ‡.

‡ Reuss.

752 Cobalt, 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 §.

§ Id.

753 Nickel, 12. Borat of nickel.—A saline substance difficultly soluble ‖.

‖ Bergman.

754 Lead, 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 ¶.

¶ Reuss.

755 Tin, 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.

756 Copper, 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.

* Bergman.

757 Bismuth, 16. Borat of bismuth.—A white powder, which melts into a white transparent permanent glass †.

† Wenzel.

758 Arsenic, 17. Borat of arsenic.—White oxide of arsenic and boracic acid form a salt soluble in water and crystallizable ‡.

‡ Reuss.

Sect. IX. *Of Fluats.*

Those salts into which fluoric acid enters are called *fluats*. They were first formed by Scheele.

759 Fluat of potass, 1. Fluat of potass. It forms a gelatinous mass almost without taste.

It dissolves readily in water. When exposed to the fire it melts without any ebulition §.

§ Scheele on Fluor.

760 Soda, 2. Fluat of soda. This salt resembles exactly the fluat of potass ‖.

‖ Ibid.

761 Ammonia, 3. Fluat of ammonia. It crystallizes in small prisms. It is deliquescent, and is partly decomposed by heat ¶.

¶ Wiegleb.

It is decomposed by

Nitrat of mercury,
——— — silver,
——— — lead.

762 Barytes, 4. Fluat of barytes. A powder which requires a large quantity of water to dissolve it *.

* Bergman.

763 Lime, 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.

Fluats. It is tasteless and nearly insoluble in water.

It is not altered by the air. Its specific gravity is about 3,1.

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 strontites. 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. 764 Magnesia,

These crystals are hardly soluble in water. Alcohol dissolves a small portion of them. Heat does not decompose them *.

* Bergman, ii. 384.

8. Fluat of alumina. A saline mass; which is sweetish, clammy, and gelatinous. 765 Alumina,

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. 766 Silica,

10. Fluat of silica and potass 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* †.

† Scheele, Crell's Journal, i. 207. Eng. Transl.

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. 767 Metallic fluats.

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 blowpipe it melts into a yellow glass, most of which evaporates by a continued heat ‡.

‡ Scheele on Fluor.

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 potass. This salt is formed by saturating potass with carbonic acid, which is best done by exposing a solution of potass for a considerable time to carbonic acid gas. 768 Carbonat of potass.

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 ¶.

‖ Bergman.

¶ Ann. de Chim. xv. 29.

It

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 $\frac{5}{6}$ths of its weight †. Alcohol, even when hot, does not dissolve above $\frac{1}{1200}$ parts of it.

* *Bergman*, i. 13.
† *Pelletier.*

According to Bergman, it is composed of 48 parts of potass, 20 of acid, and 32 of water. According to Pelletier, of 43 parts of acid, 40 of potass, 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 ‡.

‡ *Id.*

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,	——— soda,
——— soda,	——— ammonia,
——— ammonia,	——— magnesia,
——— magnesia,	——— alumina,
——— alumina,	Acetite of barytes,
Muriat of barytes,	——— lime,
——— lime,	——— ammonia,
——— ammonia,	——— magnesia,
——— magnesia,	——— alumina,
——— alumina,	Oxy-muriat of mercury,
——— soda §,	Phosphat of lime ‖.
Nitrat of lime,	

§ *Bergman.*
‖ *Id.*

When potass 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 potass from that earth.

769 Carbonat of soda,

2. Carbonat of soda. This salt may be formed in the same manner with carbonat of potass.

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 potass.

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 ¶.

¶ *Bergman*, i. 18.

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 †.

‡ *Bergman.*
* *Id.*
† *Id.*

770 Carbonat of ammonia,

3. Carbonat of ammonia. This salt forms octahedral crystals, having for the most part their two opposite apexes truncated ‡.

‡ *Bergman*, i. [illegible]

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.

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,	

771 Carbonat of barytes,

4. Carbonat of barytes. This salt has been found native.

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 $\frac{1}{4304}$ part, and boiling water $\frac{1}{2304}$ part of this salt. Water saturated with carbonic acid dissolves $\frac{1}{830}$th part*.

* *Fourcroy, Ann. de Chim.* iv. 64.

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 †.

† *Bergman*, i. 21.

It is not altered by exposure to the air.

It is decomposed by the application of a very violent heat ‡.

‡ *Dr Hope.*

By compound affinity it is decomposed by the following salts:

Sulphat of soda,	Nitrat of alumina,
——— lime,	Muriat of lime,
——— ammonia,	——— ammonia,
——— magnesia,	——— magnesia,
——— alumina,	——— alumina,
Nitrat of soda,	Acetite of lime,
——— lime,	——— magnesia,
——— ammonia,	——— alumina.
——— magnesia,	

772 Carbonat of lime.

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.

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 $\frac{1}{1500}$ part of it; from this solution it gradually precipitates as the acid leaves it in the form of small rhomboidal crystals §.

§ *Bergman*, i. 21.

It is composed, according to Bergman, of 34 parts of acid, 11 of water, and 55 of lime.

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.

773 Carbonat of strontites,

6. Carbonat of strontites. This salt, which was first examined by Dr Hope, is insipid, and soluble in 1536 parts

Carbonats.

parts of boiling water. It is compoſed of 30,2 parts of acid, 69,8 of ſtrontites. A violent heat decompoſes it *.

* Hope, Tranſ. Edin. iv. 5.

7. Carbonat of magneſia. This ſalt may be formed by ſaturating the common magneſia of the ſhops with carbonic acid gas.

774 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.

† Butini ſur la Magneſie.

Water at the temperature of 50 diſſolves $\frac{1}{48}$ 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 §.

‡ Fourcroy, Ann. de Chim. ii. 298.

§ Butini.

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 ||.

|| Fourcroy, ibid.

When heated, it decrepitates, falls into powder, and is decompoſed ¶.

¶ Id. ibid.

The following ſalts decompoſe it by compound affinity:

Sulphat of lime,	Nitrat of lime,
——— ammonia,	Muriat of lime,
——— alumina,	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 $\frac{1}{10000}$ 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.

† Bergman, i. 33.

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.

‡ Ibid.

100 parts of	By Bergman. Precipitated by Carb. of Soda. Weight.	By Wenzel. Precipitated by Carb. of Potaſs. 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:

Acetites.

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*.

777 Acetite of potaſs.

1. Acetite of potaſs. 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. It has received a great number of names; as, for inſtance, *arcanum tartari*, *ſecret foliated earth of tartar*, *eſſential ſalt of wine*, *regenerated tartar*, *diuretic ſalt*, *digeſtive ſalt of Sylvius*.

* Plinii, l. xxiii. *proœmium*.

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$\frac{4}{9}$ths of potaſs. And from the experiments of Dr Higgins, it appears that acetite of potaſs is compoſed of 61,5 parts of alkali and 38,5 of acetous acid and water ‡.

‡ On Acetous Acid, p. 8.

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,	Nitrat of ammonia,
——— lime,	——— magneſia,
——— ammonia,	——— alumina,
——— magneſia,	——— biſmuth,
——— alumina,	——— mercury,
Nitrat of ſoda,	Muriat of ammonia,
——— lime,	——— alumina.

778 Acetite of ſoda.

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° §.

§ Bergman, ibid.

According to Wenzel, 440 parts of acetous acid require for ſaturation 157$\frac{3}{7}$ths of ſoda.

It is not affected by expoſure to the air.

When heated, it firſt loſes its water of cryſtallization; in

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 depoſite needle-ſhaped cryſtals. Mr de Laſſone cryſtallized it by ſublimation *. When the ſublimation is ſlow, it forms long, ſlender, flatted 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 potaſs,	Nitrat of ſilver ¶.

* *Mem. Par.* i. 775.
† *Higgins on Acetous Acid*, p. 188.
‡ *Higgins, ibid*, p. 192.
§ *Ibid.*
‖ *Ibid.*
¶ *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 potaſs,	Nitrat of alumina,
——— ſoda,	Muriat of potaſs,
——— lime,	——— ſoda,
——— ammonia,	——— lime,
——— magneſia,	——— ammonia,
——— alumina,	——— magneſia,
Nitrat of potaſs,	——— alumina,
——— ſoda,	Carbonat of potaſs,
——— lime,	——— ſoda,
——— ammonia,	——— ammonia.
——— magneſia,	

* *Morveau, Encyc. Method. Chim.* i. 8.

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 ſatin.

Its taſte is bitter and ſour, becauſe it has an exceſs of acid.

It is ſoluble in water.

† *Plinii*, l. xxxvi. c. 24.

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,	——— potaſs,
——— alumina,	——— ſoda,
Nitrat of ammonia,	——— ammonia,
——— magneſia,	——— magneſia,
——— alumina,	——— alumina.
Muriat of ammonia,	

* *Encyc. Method. Chim.* i. 9.
† *On Acetous Acid*, p. 47.
‡ *Ibid. Encyc. Method.*

782 Acetite of ſtrontites. 6. 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 §.

§ *Dr Hope, Tranſ. Edin.* iv. 14.

783 Acetite of magneſia. 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 123¾ths 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,	——— potaſs,
Nitrat of ammonia,	——— ſoda,
——— alumina,	——— ammonia,
Muriat of ammonia,	——— alumina.
——— alumina,	

‖ *Bergman*, ii. 388.
¶ *Morveau, ibid.*
* *Bergman*, ii. 388.

784 Acetite of alumina. 8. Acetite of alumina. This ſalt can only be formed by digeſting acetous acid on alumina recently precipitated.

By evaporation needle-ſhaped cryſtals are obtained, which are very deliqueſcent. According to Wenzel, 240 parts of acetous acid require 20¾ths of alumina for ſaturation.

This ſalt is decompoſed by compound affinity by the following ſalts:

Nitrat of ammonia,	Carbonat of potaſs,
Muriat of ammonia,	——— ſoda,
Carbonat of barytes,	——— ammonia.

785 Acetite of jargonia. 9. Acetite of jargonia. This ſalt may be formed by pouring acetous acid on newly precipitated jargonia. 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.

† *Klaproth, Journ. de Phyſ.* xxxvi. 188.

Acetites.

hol. It is not ſo eaſily decompoſed by heat as nitrat of jargonia, probably becauſe it does not adhere ſo ſtrongly to water *.

* Vauquelin, Ann. de Chim. xxii. 206.

786 Acetite of iron.

10. Acetite of iron.—This ſalt was mentioned by Schrœder 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 $186\frac{1}{4}$ 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 $195\frac{5}{6}$ths 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 mangneſe.—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 $241\frac{5}{7}$ths of cobalt.

789 Acetite of nickle.

14. Acetite of nickel.—This ſalt forms rhomboidal cubes of a green colour ‡: They are not deliqueſcent: Their taſte is ſweet §.

‡ Bergman.
§ 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 parallelopipeds, 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 potaſs ‖,
Phoſphat of ſoda,	Malat of potaſs ¶.

‖ Scheele.
¶ Id.

791 Acetite of tin.

16. Acetite of tin.—This ſalt was firſt deſcribed by Lemery.

Its cryſtals are priſmatic needles in groups *. According to Wenzel, 240 parts of acetous acid require for ſaturation $3\frac{5}{11}$ of tin.

* Morveau.

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.* 792 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 $16\frac{1}{8}$th of copper for ſaturation.

It effloreſces when expoſed to the air. Heat decompoſes it. It is uſed in painting.

18. Acetite of biſmuth.—This ſalt ſeems to have been firſt mentioned by Geoffroi. He called it *ſugar of biſmuth.* 793 Acetite of biſmuth.

It is moſt eaſily procured by mixing together the ſolutions of nitrat of biſmuth and acetite of potaſs. It forms brilliant, talky, ſilvery cryſtals.

It has a ſweetiſh taſte. According to Wenzel, 240 parts of acetous acid require for ſaturation $15\frac{5}{9}$ths of biſmuth.

It does not deliqueſce when expoſed to the air. Heat decompoſes it.

19. Acetite of antimony.—It yields with difficulty ſmall cryſtals †. According to Wenzel, 240 parts of acetous acid require for ſaturation $1\frac{1}{3}$d of antimony. 794 Acetite of antimony.

† Wenzel.

20. Acetite of arſenic.—This ſalt forms ſmall cryſtals in grains, hardly ſoluble in water ‡. 795 Acetite of arſenic.

‡ Bergman.

21. Acetite of mercury.—This ſalt is mentioned by Schrœder. 796 Acetite of mercury.

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 $240\frac{3}{7}$ths of mercury.

When expoſed to the air it becomes black, owing to the reduction of the oxide of mercury. Heat decompoſes it.

22. Acetite of ſilver.—This ſalt was perhaps firſt deſcribed by Margraf. 797 Acetite of ſilver.

It is beſt formed by dropping acetite of ſoda or potaſs 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 $101\frac{4}{9}$ths of ſilver.

Heat decompoſes it. It is decompoſed by muriat of magneſia ¶.

¶ Bergman.

23. Acetite of gold.—This ſalt is mentioned by Schrœder and Juncker. 798 Acetite of gold.

24. Acetite of uranium.—This ſalt was firſt formed by Klaproth. 799 Acetite of uranium.

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.

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. 800 Acetats.

Sect. XII. *Of Oxalats.*

The compounds of which oxalic acid forms a part are

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 first proved that it contained potafs; and Scheele difcovered that its acid is the oxalic. A great many interefting experiments had been previoufly made on it by Wenzel and Wiegleb.

It may be formed, as Scheele has fhown, 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.

Its cryftals are fmall opaque parallelopipeds †.

† *De Lifle.*

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 decompofes 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 redden the infufion of turnfole.

They are eafily foluble in water, but not in alcohol ‡.

‡ *Bergman.*

It is decompofed by nitrat of barytes §.

§ *Bergman, ibid.*

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 decompofes 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 decompofes it by deftroying the acid *.

* *Hope, Tranf. Edin.* iv. 14.

8. Oxalat of magnefia.—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 magnefia and 65 of acid and water. Heat decompofes it †.

† *Bergman, ibid.* and ii. 387.

9. Oxalat of alumina.—It is uncryftallizable; but furnifhes on evaporation a yellowifh pellucid mafs. It is fparingly foluble in alcohol. It has a fweet aftringent tafte. It is compofed of 44 parts of alumina and 56 of acid and water.

When expofed to the air it deliquefces; and if it has been previoufly well dried, its weight is increafed by $\frac{2}{3}$. It reddens turnfole *.

* *Bergman, ibid.*

806 Metallic oxalats.

10. Oxalat of iron.—This falt forms prifmatic cryftals of a yellowifh green colour.

It has an aftringent 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 †.

† *Ibid.*

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 manganefe.—It is compofed of oxalic acid and white oxide of manganefe. 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 aufter 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 uncryftallizable. It is a bluifh 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 bifmuth.—This falt may be formed by dropping oxalic acid into a folution of nitrat of bifmuth. It forms pellucid polygonous cryftals. When oxide of bifmuth is diffolved 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 arfenic.—This falt is compofed of oxalic acid and white oxide of arfenic. Its cryftals are prifms very foluble in water and alcohol. It reddens turnfole.

Heat fublimes it; and by a ftrong heat it may be decompofed ¶.

¶ *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 Tartar.

1. Acidulous oxalat of potafs or tartar.—This falt, 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 ftate of impurity at the bottom, and adhering to the fides of cafks in which wine has fermented. It is called *tartar*, fays Paracelfus, becaufe it produces the oil, water, limeftone, and falt, which burn the patient as *Hell* does. According to him, it was the principle of every difeafe and every remedy, and all things contain the germ of it.

Margraf and Rouelle firft demonftrated that it contained potafs ready formed: and Scheele firft obtained tartarous acid from it in a ftate of purity.

Its cryftals are very fmall and irregular. According to Montet, they are prifms, fomewhat flat, and moftly with fix fides. It has a ftrong acid tafte. It is foluble in about 30 times its weight of boiling water*. According to Bergman, it contains 23 parts of alkali and 77 of acid.

* Wenzel.

It is not altered by expofure to the air. Heat decompofes it, and at the fame time deftroys the acid. It is capable of forming a great many compounds.

808 Tartrite of potafs.

2. Tartrite of potafs. This falt may be formed by faturating the laft defcribed falt with potafs. It was formerly called *foluble tartar*, becaufe it is much more foluble in water than the acidulous tartrite of potafs. It cryftallizes moft readily when there is a fmall excefs of alkali in the folution. Its cryftals are fmall oblongs.

It has an unpleafant bitter tafte. It is foluble in 4 parts of water at the temperature of 40°.

3. Tartrite of foda. This falt has never been accurately examined.

809 Tartrite of potafs and foda.

4. Tartrite of potafs and foda. This triple falt, formerly known by the name of *falt of Seignette*, becaufe firft formed by Mr Seignette apothecary at Rochelle, is made by faturating tartar with foda.

Its cryftals are prifms of eight or ten unequal fides, having their ends truncated at right angles. They are generally divided into two in the direction of their axes, and the bafe on which they ftand is marked with two diagonal lines, fo as to divide it into four triangles.

It has a bitter tafte. It is almoft as foluble as tartrite of potafs.

It effloresces when expofed to the air. Heat decompofes it.

810 Tartrite of ammonia.

4. Tartrite of ammonia. The cryftals of this falt are polygonous prifms, not unlike thofe of the laft defcribed falt.

It has a cooling bitter tafte like that of nitre. It is eafily foluble in water. Heat decompofes it.

5. Acidulous tartrite of ammonia. This falt may be formed by pouring tartarous acid into a folution of tartrite of ammonia. Like acidulous tartrite of potafs it is very infoluble in water.

6. Tartrite of potafs and ammonia. This triple falt may be formed by pouring ammonia into acidulous tartrite of potafs.

Its cryftals, according to Macquer, are prifms with four, five, or fix fides: according to the Dijon academicians, parallelopipeds, with two alternate floping fides.

It has a cooling tafte. It is foluble enough in water. It effloresces in the air. Heat decompofes it.

811 Earthy tartrites.

7. Tartrite of barytes. Unknown.

8. Tartrite of lime. This falt, firft formed by Scheele, is a taftelefs and almoft infoluble powder. By heat the acid is decompofed, and the pure lime remains behind.

9. Tartrite of ftrontites. This falt was firft formed by Dr Hope. Its cryftals are fmall regular triangular tables, having the edges and angles fharp and well defined. It is infipid. It diffolves in 320 parts of boiling water.

It is not altered by expofure to the air. Heat decompofes it by deftroying the acid*.

* Hope, Edin. Tranf. iv. 15.

10. Tartrite of magnefia. This falt is infoluble in water except there be an excefs of acid prefent. It then affords by evaporation fmall cryftals in the form of hexangular truncated prifms†.

It has a more faline tafte, and is more fufible, than tartrite of lime‡.

Heat firft melts and afterwards decompofes it.

† Bergman, ii. 288.

‡ Von Packen de Sale effent. acid. Tartar.

11. Tartrite of alumina. This falt does not cryftallize, but forms by evaporation a clear tranfparent gummy mafs. Its tafte is aftringent. It is foluble in water. It does not deliquefce in the air §.

§ Von Packen.

12. Tartrite of potafs and alumina. This triple falt is formed by faturating tartar with alumina. It bears a very ftriking refemblance to the laft defcribed falt.

812 Metallic tartrites.

13. Tartrite of iron. This is a grey powder. When tartarous acid is poured into a folution of fulphat of iron, fcaly cryftals are formed by evaporation. Thefe cryftals are doubtlefs compofed of tartarous acid combined with fulphat of iron. This triple falt might be called *tartro-fulphat of iron*.

14. Tartrite of potafs and iron. This triple falt was formerly called *tartarifed tincture of Mars*, *chalybeated tartar*, and *tartarifed iron*. It may be formed by boiling two parts of tartar and one of iron filings, previoufly made up into a pafte, in a proper quantity of water. The liquor by evaporation depofites cryftals, which form the falt wanted.

15. Tartrite of zinc. This falt is not eafily foluble in water.

16. Tartrite of potafs and zinc. This triple falt, formed by combining tartar and oxide of zinc, is very foluble in water ‖.

‖ Elemens. de Chim. Dijon.

17. Tartrite of lead. This falt, which is compofed of tartarous acid and white oxide of lead, is almoft infoluble in water. Nitric acid diffolves it.

18. Tartrite of potafs and lead. This falt, formed by combining white oxide of lead with tartar, is very foluble in water ¶.

¶ Wenzel.

19. Tartrite of tin. Unknown. The tartrite of potafs and tin, compofed of tartar and oxide of tin, is capable of cryftallizing.

20. Tartrite of copper. This falt is beft formed by pouring tartarous acid into the folutions of muriat or fulphat of copper; it precipitates in the form of blue cryftals *.

* Bergman.

This falt forms the beft kind of the pigment called *Brunfwick green* †.

† Leonbardi.

21. Tartrite of potafs and copper. This triple falt is alfo in the form of blue cryftals.

22. Tartrite of bifmuth. Small cryftalline grains ‡.

‡ Bergman.

23. Tartrite of antimony. This falt has never been examined with attention.

24. Tartrite of potafs and antimony, or tartar emetic. To this falt, which is perhaps the moft powerful emetic known, a great deal of attention has been paid, and a vaft number of methods have been tried to prepare it. Thefe methods have been already defcribed in the Encyclopædia. It appears from the experiments of Mr Bindheim,

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. Tartrite of arſenic. This ſalt forms priſmatic cryſtals very like thoſe of oxalat of arſenic †.

† Bergman, i. 295.

26. Tartrite of mercury. A yellow powder.

27. Tartrite of potaſs and mercury. This triple ſalt cryſtallizes ‡.

‡ Monnet.

Sect. XIV. *Of Citrats.*

The compounds into which the citric acid enters have been denominated *citrats*.

These ſalts are at preſent very imperfectly known. Mr Dizé has promiſed ſoon to ſupply this defect §.

§ Journ. de Phyſ. 1794, Supplement.

813 Alkaline citrats.

1. Citrat of potaſs. 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.

‖ Dr Donald Monro, Phil. Tranſ. 57.

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 *.

¶ Dobſon. * Scheele.

814 Earthy citrats.

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.

† Id.

5. Citrat of lime. This is a white powder, ſcarcely ſoluble in water ‡.

‡ Id.

6. Citrat of magneſia. Does not cryſtallize. It forms a gummy ſaline maſs very ſoluble in water §.

§ Id.

7. Citrat of alumina. This ſalt is ſcarcely ſoluble in water.

815 Metallic citrats.

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 ‖.

‖ Dizé.

Sect. XV. *Of Malats.*

816 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.

1. Malat of potaſs.
2. Malat of ſoda.
3. Malat of ammonia.

} These ſalts are deliqueſcent ¶.

¶ Scheele.

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 ‡.

† Id. ‡ Id.

5. Malat of barytes. The properties of this ſalt reſemble pretty much thoſe of malat of lime §.

§ Id.

6. Malat of magneſia. Deliqueſcent ‖.

‖ Id.

7. Malat of iron. A brown ſolution, not cryſtallizable *.

Lactats.

8. Malat of zinc. This ſalt forms beautiful cryſtals †.

* Scheele. † Id.

Sect. XVI. *Of Lactats.*

817 Lactats.

The neutral ſalts formed by the combination of the lactic acid with various baſes are called *lactats*. They were firſt diſcovered by Scheele.

1. Lactat of potaſs. A deliqueſcent ſalt, ſoluble in alcohol ‡.

‡ Scheele on Milk.

2. Lactat of ſoda. This ſalt does not cryſtallize. It is ſoluble in alcohol §.

§ Ibid.

3. Lactat of ammonia. Cryſtals which deliqueſce. Heat ſeparates a great part of the ammonia before deſtroying the acid.

4. Lactat of barytes.
5. Lactat of lime.
6. Lactat of alumina.

} These ſalts deliqueſce ‖. The lactat of lime is ſoluble in alcohol ¶.

‖ Ibid. ¶ Ibid.

7. Lactat of magneſia. Small deliqueſcent cryſtals *.

* Ibid.

8. Lactat of iron. A brown ſolution.

9. Lactat of zinc. Cryſtals †.

† Ibid.

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.*

818 Saccholats.

The compounds into which the ſaccholactic acid enters are called *ſaccholats*. They alſo were firſt diſcovered by Scheele.

1. Saccholat of potaſs. Small cryſtals, ſoluble in eight times their weight of boiling water ‡.

‡ Scheele on Sugar of Milk.

2. Saccholat of ſoda. The ſame; ſoluble in five times their weight of boiling water §.

§ Ibid.

3. Saccholat of ammonia. A ſalt which has a ſouriſh taſte. Heat ſeparates the ammonia ¶.

¶ Ibid.

4. Saccholat of barytes.
5. Saccholat of lime.
6. Saccholat of magneſia.
7. Saccholat of alumina.

} Theſe ſalts are inſoluble in water *.

* Ibid.

Sect. XVIII. *Of Gallats.*

819 Gallats.

The compounds into which the gallic acid enters are denominated *gallats*. They were firſt attended to by the Dijon academicians and by Scheele.

1. Gallat of potaſs.
2. Gallat of ſoda.
3. Gallat of ammonia.

} We only know that theſe compoſitions are poſſible, and that their properties are different from thoſe of all other ſalts.

4. Gallat of barytes.
5. Gallat of lime.

} Theſe ſalts are ſoluble in water, eſpecially when there is exceſs of acid.

6. Gallat of magneſia. This ſalt is a yellow powder, ſoluble in water and in alcohol *.

* Bartholdi Ann. de Chim. xii. 305.

7. Gallat of alumina. This ſalt, according to Bartholdi, exiſts ready formed in nut galls. It is very ſoluble in water.

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 falts. 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 potafs. This falt forms pointed feathery cryftals. It has a faline fharp tafte. It is very foluble in water. It deliquefces when expofed to the air *.

2. Benzoat of foda. The cryftals of this falt are larger, but its tafte is the fame with that of benzoat of potafs. It is alfo very foluble in water. It effloresces in the air †.

3. Benzoat of ammonia. This falt cryftallizes with difficulty. Its cryftals are feather-fhaped. It deliquefces ‡.

821 Earthy benzoats. 4. Benzoat of lime. This falt forms white, fhining, pointed cryftals, of a fweetifh tafte, and not eafily foluble in water §.

5. Benzoat of magnefia. Feather-fhaped cryftals, of a fharp bitter tafte, and eafily foluble in water †.

6. Benzoat of alumina, an aftringent falt.

822 Metalline benzoats. 7. Benzoat of iron. This falt forms yellow cryftals. It has a fweet tafte. It is foluble in water and alcohol. It efflorefces in the air. Heat difengages the acid ¶.

8. Benzoat of zinc. This falt forms arborefcent cryftals. It is foluble in water and alcohol. When expofed to the air it is diffipated. Heat decompofes it *.

9. Benzoat of manganefe. This falt, which is formed of benzoic acid and white oxide of manganefe, cryftallizes in fmall fcales. It diffolves readily in water; with difficulty in alcohol. It is not altered by expofure to the air †.

10. Benzoat of cobalt. Flat cryftals ‡.

11. Benzoat of lead. Very white cryftals, foluble in water and alcohol. They are not altered by expofure to the air. Heat difengages the acid §.

12. Benzoat of tin. This falt may be formed by pouring benzoat of potafs into a folution of tin in the nitro-muriatic acid. The benzoat of tin is precipitated. It is foluble in hot water, but infoluble in alcohol. Heat decompofes it ||.

13. Benzoat of copper. Small cryftals of a deep green colour. They are with difficulty foluble in water, and not at all in alcohol ¶.

14. Benzoat of bifmuth. This falt forms white needle-fhaped cryftals. They are foluble in water, and in a very fmall proportion in alcohol. They are not altered by expofure to the air. Heat decompofes them *.

15. Benzoat of antimony. Cryftals which efflorefce in the air, and are decompofed by heat †.

16. Benzoat of arfenic. Small feather-fhaped cryftals. It is foluble in hot water, but cryftallizes in the cooling. A moderate heat fublimes it; a ftrong heat decompofes it. Sulphur decompofes it. It is not decompofed by alkalies ‡.

17. Benzoat of mercury. A white powder. It is infoluble in water, but diffolves in a fmall quantity in alcohol. It is not altered by expofure to the air. A fmall heat fublimes it; a greater decompofes it. It is decompofed by fulphur §.

18. Benzoat of filver. This falt is foluble in water, and alfo in a very fmall proportion in alcohol. It is not altered by expofure to the air, but the rays of the fun render it brown. Heat difengages its acid *.

19. Benzoat of gold. Small irregular cryftals, not eafily foluble in water; infoluble in alcohol. It is not altered by expofure to the air. Heat decompofes it †.

20. Benzoat of platinum. This falt forms fmall brownifh cryftals, with difficulty foluble in water; not foluble in alcohol. When expofed to heat, it is decompofed, and there remains behind a brown powder ‡.

* Keir's Dictionary.
† Ibid.
‡ Ibid.
§ Ibid.
† Ibid.
¶ Trommfdorf, Ann de Chim. xi. 314.
* Id. ibid.
† Id. ibid.
‡ Id. ibid.
§ Id. ibid.
|| Id. ibid.
¶ Id. ibid.
* Id. ibid.
† Id. ibid.
‡ Id. ibid.
§ Id. ibid.
* Id. ibid.
† Id. ibid.
‡ Id. ibid.

SECT. XX. *Of Succinats.*

THE neutral falts, formed by the combination of the fuccinic acid with various bafes, have been called *fuccinats*.

We fhall not defcribe thefe falts, 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 falts into the compofition of which camphoric acid enters, have been denominated *camphorats*. The only chemift who has hitherto examined them is Bouillon la Grange: his experiments have been publifhed in the 27th volume of the *Annales de Chimie*.

1. Camphorat of potafs. To prepare this falt, carbonat of potafs is to be diffolved in water, and the folution faturated with camphoric acid. When the effervefcence is over, the liquor is to be evaporated by a gentle heat to the proper confiftence, and cryftals of camphorat of potafs will be depofited when the liquor cools. 823 Camphorat of potafs.

Camphorat of potafs is white and tranfparent; its cryftals are regular hexagons. Its tafte is bitterifh and flightly aromatic.

Water at the temperature of 60° diffolves $\frac{1}{100}$th part of its weight of this falt; boiling water diffolves $\frac{1}{4}$th part of its weight.

It is foluble in alcohol, and the folution burns with a deep blue flame.

When expofed to moift air, it lofes a little of its tranfparency, but in dry air it fuffers no change.

When expofed to heat it melts, fwells, and the acid is volatilized in a thick fmoke, which has an aromatic odour. Before the blow-pipe it burns with a blue flame, and the potafs remains behind in a ftate of purity.

By compound affinity this falt is decompofed by

Nitrat of barytes,
All the falts whofe bafe is lime,
Nitrat of filver,
Sulphat of iron,
Muriat of tin,
——— lead §.

2. Camphorat of foda. This falt may be formed precifely in the fame manner with the camphorat of potafs.

824 Camphorat of foda. It is white and tranfparent; its tafte is fomewhat bitter; its cryftals are irregular.

Water at the temperature of 60° diffolves lefs than $\frac{1}{200}$th part of its weight of this falt; boiling water diffolves $\frac{1}{8}$th of its weight.

It is alfo foluble in alcohol.

When expofed to the air it lofes its tranfparency, and efflorefces

§ Bouillon La Grange, Ann. de Chim. xxvii. 24.

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 many other salts with me-
——— alumina,	

tallic bases *.

* Bouillon La Grange, Ann. de Chim. xxvii. 26.

825 Camphorat of ammonia.

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.

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 $\frac{1}{600}$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 Camphorat of lime.

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 $\frac{3}{4}$ths of its volume. On cooling, camphorat of lime is deposited.

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 $\frac{1}{200}$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 La Grange, Ann. de Chim. xxvii. 21.

828 Camphorat of magnesia.

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 †.

† Id. 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 confiderable quantities; but it precipitates again as the folution cools.

Alcohol, while cold, diffolves it very fparingly; but when hot it diffolves a confiderable quantity of it, which precipitates alfo as the folution cools.

This falt undergoes very little alteration in the air; but it rather parts with than attracts moifture.

Heat volatilizes the acid; and when the falt is thrown on burning coals it burns with a blue flame.

It is decompofed by the nitrats of lime and barytes *.

* Bouillon La Grange, Ann. de Chim. xxvii. 34.

Sect. XXII. *Of Suberats.*

The falts formed by the fuberic acid have obtained the appellation of *fuberats*. They have hitherto been examined only by Bouillon la Grange.

830 Suberat of potafs.

1. Suberat of potafs.—This falt ought to be formed by means of cryftallized carbonat of potafs.

It cryftallizes in prifms, having four unequal fides. It has a bitter faltifh tafte, and it reddens vegetable blues. It is very foluble in water. Caloric melts it, and at laft volatilizes the acid.

It is decompofed by moft of the metallic falts, and by fulphat of alumina, muriat of alumina, and of lime; nitrat of alumina and of lime; and phofphat of alumina †.

† Id. ibid. xxiii. 52.

831 Suberat of foda.

2. Suberat of foda.—This falt does not cryftallize. It reddens the tincture of turnfole. Its tafte is flightly bitter. It is very foluble in water and in alcohol. It attracts moifture from the air. Caloric produces the fame effect on it that it does on fuberat of potafs.

It is decompofed by the calcareous, aluminous, and magnefian falts ‡.

‡ Id. ibid. p. 53.

832 Suberat of ammonia.

3. Suberat of ammonia.—This falt cryftallizes in parallelopipeds Its tafte is faltifh, and it leaves an impreffion of bitternefs: It reddens vegetable blues.

It is very foluble in water. It attracts moifture from the air. When placed upon burning coals, it lofes its water of cryftallization, and fwells up; and before the blow-pipe it evaporates entirely.

It is decompofed by the aluminous and magnefian falts §.

§ Id. ibid. p. 55.

833 Suberat of barytes.

4. Suberat of barytes.—This falt does not cryftallize. Heat makes it fwell up, and melts it. It is fcarcely foluble in water except there be an excefs of acid.

It is decompofed by moft of the neutral falts, except the barytic falts and the fluat of lime ||.

|| Id. ibid. p. 52.

834 Suberat of lime.

5. Suberat of lime.—This falt does not cryftallize. It is perfectly white: It has a faltifh tafte: It does not redden the tincture of turnfole.

It is very fparingly foluble in water except when hot; and as the folution cools moft of the falt precipitates again.

When placed upon burning coals it fwells up, the acid is decompofed, and there remains only the lime in the ftate of powder.

It is decompofed by

- The muriat of alumina,
- The carbonats of potafs and foda,
- The fluat of magnefia,
- The phofphats of alumina and foda,
- The borat of potafs,
- All the metallic folutions ¶.

¶ Id. ibid. p. 54.

835 Suberat of magnefia.

6. Suberat of magnefia.—This falt is in the form of a powder:. It reddens the tincture of turnfole. It has a bitter tafte: It is foluble in water, and attracts fome moifture when expofed to the air.

Pruffiats.

When heated it fwells up and melts: before the blow-pipe the acid is decompofed, and the magnefia remains in a ftate of purity.

It is decompofed by

- Muriat of alumina,
- Nitrat of lime and alumina,
- Borat of potafs,
- Fluat of foda,
- Phofphat of alumina *.

* Bouillon La Grange, Ann. de Chim. xxiii. 55.

836 Suberat of alumina.

7. Suberat of alumina.—This falt does not cryftallize. When its folution is evaporated by a moderate heat in a wide veffel, the falt obtained is of a yellow colour, tranfparent, having a ftyptic tafte, and leaving an impreffion of bitternefs on the tongue. When too much heat is employed it melts and blackens. It reddens the tincture of turnfole, and attracts moifture from the air. Before the blow-pipe it fwells up, the acid is volatilized and decompofed, and nothing remains but the alumina.

It is decompofed by

- The carbonats of potafs and foda,
- The fulphat of iron,
- The muriat of iron,
- The nitrats of filver, mercury, and lead †.

† Id. ibid.

Suberic acid forms alfo compounds with the oxides of filver, mercury, lead, copper, tin, iron, bifmuth, arfenic, cobalt, zinc, antimony, manganefe, and molybdenum; moft of which are incryftallizable, and have an excefs of acid ‡.

‡ Id. ibid. p. 57.

Sect. XXIII. *Of Pruffiats.*

The compounds into which the pruffic acid enters are called *Pruffiats*.

Thefe fubftances, the moft important of which are triple falts, have fomething very peculiar in their affinities. The pruffic acid appears to have a ftronger affinity for alkalies and earths than for metals, at leaft thefe fubftances are capable of decompofing metallic pruffiats; yet acids fcarcely decompofe the metallic pruffiats, while the weakeft acid known decompofes the pruffiats of alkalies and earths. Thefe phenomena have not yet been fatisfactorily accounted for.

837 Alkaline pruffiats.

1. Pruffiat of potafs.
2. Pruffiat of foda.

} Thefe falts were firft obtained pure by Mr Scheele. They are foluble in water; but they are of little ufe, as mere expofure to the air decompofes them.

3. Pruffiat of ammonia.—This falt has the fmell of ammonia. It is very volatile and as eafily decompofed as the other two.

838 Earthy pruffiats.

4. Pruffiat of lime.—This falt is foluble in water. It is alfo decompofed by expofure to the air.

5. Pruffiat of barytes.
6. Pruffiat of magnefia.

} Thefe falts are alfo foluble in water, and decompofed by all acids.

Pruffic acid does not combine with alumina.

839 Pruffian blue.

7. Pruffiat of iron, or Pruffian blue.—This fubftance is compofed, as Mr Prouft has fhewn, of the pruffic acid and brown oxide of iron. With the green oxide the pruffic acid forms a white compound, which, however, becomes gradually blue when expofed to the atmofphere, becaufe the oxide abforbs oxygen, and is converted into brown oxide §.

§ Nicholfon's Jour. i. 453.

Pruffiat of iron is a deep blue coloured powder. It is

Pruffiats. is infoluble in water, and fcarcely foluble in acids. It is compofed, according to the moft accurate experiments hitherto made, of equal parts of oxide of iron and pruffic acid. It is not affected by expofure to the air. Heat decompofes it by deftroying the acid, and the oxide of iron remains behind.

The Pruffian blue of commerce, befides other impurities, contains mixed with it a great quantity of alumina. Its ufe as a pigment, and the attempts which have been made to introduce it as a dye, are well known.

Pruffiat of iron may alfo exift in another ftate: It may have a fuperabundance of oxide; its colour is then more or lefs yellow. To this ftate it may be reduced by digefting it with alkalies or any of the alkaline earths. Thefe fubftances deprive it of part of its acid, but not of the whole.

This yellow pruffiat is foluble in acids.

840 Affinities of the pruffic acid explained.

Were we to attempt an explanation of this, and the other phenomena which the pruffic acid difplays in its combinations, we would conjecture, that this yellow pruffiat is the fubftance formed by the direct combination of brown oxide of iron and pruffic acid, and that the blue pruffiat is formed of the yellow pruffiat combined as an integrant with pruffic acid: That the affinity between the pruffic acid and oxide of iron is much ftronger than that between yellow pruffiat of iron and pruffic acid; that therefore alkalies and earths have a ftronger affinity for pruffic acid than the yellow pruffiat has, but a much weaker affinity than oxide of iron, and perhaps every other oxide;—hence the apparent fuperiority of alkalies and earths in fome cafes, while in others they appear very inferior. We would fuppofe, then, that the pruffic acid has a much ftronger affinity for oxide of iron, and perhaps for all other oxides, than for other bodies; that the pruffiats, thus formed, are capable of combining with pruffic acid; but that their affinity for it is much lefs than that of the alkalies and earths. This conjecture is fupported by all the phenomena at prefent known; it would remove all the apparent anomalies which the combinations of this fingular acid prefent, and reduce the whole of them under the known laws of affinity.

841 Properties of Pruffian alkali,

8. Pruffiat of potafs and iron, commonly called *Pruffian alkali*, or *Pruffian teft*. This fubftance is a triple falt, compofed of pruffic acid, potafs, and oxide of iron combined together. To chemifts and mineralogifts it is one of the moft important inftruments ever invented; as, when properly prepared, it is capable of indicating whether any metallic fubftance (platinum excepted) be prefent in any folution whatever, and even of pointing out the particular metal, and of afcertaining its quantity: This it does by means of a compound affinity, which, after what has been faid above, may be eafily underftood. The Pruffian alkali may be conceived to be a combination of two fubftances, pruffiat of potafs and blue pruffiat of iron. Now every metallic oxide has a ftronger affinity for pruffic acid than potafs has (and, in fact, feems to have a ftronger affinity for it than for any other fubftance). If, therefore, there happen to be any oxide in the folution, it immediately feizes the pruffic acid with which the potafs is combined, and by that means decompofes the triple falt. A pruffiat of the particular metal is formed, and, as moft pruffiats of metals are infoluble, it is precipitated; and it indicates by its colour the particular metal, and by its weight the quantity of metal that happens to be prefent. At the fame time the blue pruffiat of iron is alfo precipitated, and its weight muft be deducted from the quantity of the precipitate.

In order to be certain of the accuracy of thefe refults, it is neceffary to have a Pruffian alkali perfectly pure, and to be certain before hand of the quantity, or rather of the proportions of its ingredients. To obtain a teft of this kind has been the object of chemifts ever fince the difcoveries of Macquer pointed out its importance. It is to the ufe of impure tefts that a great part of the contradictory refults of mineralogical analyfes by different chemifts is to be afcribed.

There are two * ways in which this teft may be rendered impure, befides the introduction of foreign ingredients, which we do not mention, becaufe it is obvious that it muft be guarded againft. 1. There may be a fuperabundance of alkali prefent, or, which is the fame thing, there may be mixed with the Pruffian teft a quantity of pure alkali; or, 2. There may be contained in it a quantity of yellow pruffiat of iron, for which pruffiat of potafs has alfo a confiderable affinity.

* See *Kirwan's Min.* i. 487.

842 Liable to impurities.

If the Pruffian teft contain a fuperabundance of alkali, two inconveniences follow. This fuperabundant quantity will precipitate thofe earthy falts which are liable to contain an excefs of acid, and which are only foluble by that excefs: Hence alumina and barytes will be precipitated. It is to the ufe of impure tefts of this kind that we owe the opinion, that barytes and alumina are precipitated by the Pruffian alkali, and the confequent theories of the metallic nature of thefe earths. This miftake was firft corrected, we believe, by Mr Klaproth.

Another inconvenience arifing from the fuperabundance of alkali in the Pruffian teft is, that it gradually decompofes the blue pruffiat which the teft contains, and converts it into yellow pruffiat. In what manner it does this will be underftood, after what has been faid, without any explanation.

On the other hand, when the Pruffian alkali contains a quantity of yellow pruffiat of iron, as great inconveniences follow. This yellow pruffiat has an affinity for pruffic acid, which, though inferior to that of the potafs, is ftill confiderable; and, on the other hand, the potafs has a ftronger affinity for every other acid than for the pruffic. When, therefore, the teft is expofed to the air, the carbonic acid, which the atmofphere always contains, affifted by the affinity between the yellow pruffiat and the pruffic acid, decompofes the pruffiat of potafs in the teft; and the yellow pruffiat is precipitated in the form of Pruffian blue: And every other acid produces the fame effect. A teft of this kind, therefore, would indicate the prefence of iron in every mixture which contains an acid (for a precipitation of Pruffian blue would appear); and could not, therefore, be trufted to with any confidence.

843 Klaproth's method of forming it.

We will not attempt to defcribe the various methods which different chemifts have adopted of preparing this teft; but fhall fatisfy ourfelves with defcribing the method of Klaproth, which anfwers the purpofe completely. This we fhall do nearly in the words of Mr Kirwan.

Prepare a pure potafs, by gradually projecting into a large crucible heated to whitenefs a mixture of equal parts of purified nitre and cryftals of tartar; when the whole is

Prussiats. 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 potass 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 potass.

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 †.

844 Prussiat of ammonia and iron.

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 prussiats ‡.

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.

845 Prussiat of mercury.

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 *.

* Kirwan's Mineral. i. 494.

† Berthollet.

‡ Woulfe, Journ. de Phys. xxxiv. 101.

* Berthollet.

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.*

Sebats.

The compounds into which the sebacic 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 sebacic acid and its combinations in the Philosophical Transactions for 1780 and 1782.

846 Alkaline sebats.

1. Sebat of potass. 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.

847 Earthy sebats.

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.

848 Metallic sebats.

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.

Metallic Acid Salts.

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.

849 Fulminating gold.

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.

850 Fulminating silver.

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.

* Berthollet, Ann. de Chim. i.

Hydrosulphurets.

851 Mercuriat of lime and of ammonia.

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 †.

* Id. ibid.

† Lavoisier, ibid.

852 Cuprat of ammonia.

5. Cuprat of ammonia. Oxide of copper dissolves in ammonia. Mr Sage has described its crystallization. It is decomposed by lime and potass, and cuprat of lime and potass are formed.

853 Stannat of gold.

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.

854 Plumbat of lime.

7. Plumbat of lime. Lime-water boiled on the red oxide of lead dissolved 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 ‡.

‡ Berthollet, Ann. de Chim. i. 37.

855 Zincat of ammonia.

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 potass also dissolve it §.

§ Id. ibid. p. 42.

856 Antimoniat of potass.

9. Antimoniat of potass. When antimony is detonated with nitre in a crucible, part of its oxide unites with the potass of the nitre ‖.

‖ Id. ibid.

Chap. III. *Of* Hydrosulphurets.

857 Properties of sulphurated hydrogen gas.

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.

¶ Ann. de Chim. xxv. 233.

858 Remarks on sulphurets.

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

Hydrosul-phurets. 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 potass in water (that is, to hydrogenous sulphuret of potass), a quantity of oxy-muriatic acid supersaturated with potass 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 potass was not sufficient to keep it dissolved, or, which is the same thing, that its affinity for potass 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. Potass has a stronger affinity for this last substance than the sulphuret; potass 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 hydrosulphurets. We shall now proceed to the method of forming the hydrosulphurets. 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 potass 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 hydrosulphurets of potass, soda, and ammonia, may be formed.

In order to form hydrosulphuret of lime, that earth was mixed with distilled water, and sulphurated hydrogen gas passed into this mixture till a sufficient quantity of hydrosulphuret 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.

Hydrosulphuret 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 hydrosulphuret 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,
Potass,
Soda,
Lime,
Ammonia,
Magnesia,
Jargonia.

Almost all the metallic oxides have a stronger affinity for sulphurated hydrogen than the earths have.

862 Properties of hydrosulphurets. When the hydrosulphurats are prepared with the necessary precautions to prevent the contact of atmospherical 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 hydrosulphuret 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 hydrosulphurets 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 hydrosulphuret 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 hydrosulphuret spontaneously absorbs oxygen. This acid, however, is not perceptible till after a certain interval of time when separated from the hydrosulphuret 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 hydrosulphurets, on which the alkalies have no action at the temperature of the atmosphere: But concentrated acids combine with the oxides of these hydrosulphurets, and separate the sulphurated hydrogen in the form of gas. 863 Metalline hydrosulphurets.

In the greater number of these metallic oxide hydrosulphurets, 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 hydrosulphurets part of the sulphur also combines with oxygen, and forms sulphuric acid.

The alkaline hydrosulphurets 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 hydrosulphuret of potass, hydrogenous sulphuret of potass, and water impregnated with sulphurated hydrogen gas, upon various metallic solutions.

Metallic

Hydrosulphurets.

Metallic Solutions.	Solution of Hydrogenous Sulphuret of Potass.	Water impregnated with Sulphurated Hydrogen Gas.	Hydrosulphuret 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 hydrosulphuret 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 hydrosulphuret.
White oxide of antimony.		Becomes yellow after some seconds.	The liquor loses its colour (A).

Metallic

(A) In these, hydrosulphuret of ammonia was used instead of hydrosulphuret of potass.

Table continued.

Metallic Solutions.	Solution of Hydrogenous Sulphuret of Potaſs.	Water impregnated with Sulphurated Hydrogen Gas.	Hydroſulphuret of Potaſs.
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 carbonat of lime ſometimes depoſited by waters that run over quantities of that mineral. 866 Suſpenſion,

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. 867 And fuſion.

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 868 Cryſtallization explained.

* *Treatiſe on the Origin of Forms and Qualities.*

Crystallization.

fequence 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 atmospherical 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.

870
And why.

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 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.

† Optics, p. 375.

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. 149.

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.

872
Hauy's theory of crystals.

But, independent of these accidental circumstances, Mr Hauy 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.

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 *psut*, and made an angle of 135°, both with the remainder of the base *abcsph* 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 *abcnih* of the prism, he attempted to detach

a

Cryſtallization.

a ſimilar ſegment in the part to which the next edge *c n* belonged, employed for that purpoſe the blade of a knife, directed in the ſame degree of obliquity as the trapezium *p s u t*, and aſſiſted by the ſtrokes of a hammer. He could not ſucceed: But upon making the attempt upon the next edge *b c*, he detached another ſegment, preciſely ſimilar to the firſt, and which had for its vertex the edge *b c*. He could produce no effect on the next edge *a b*; but from the next following, *a h*, he cut a ſegment ſimilar to the other two. The ſixth edge likewiſe proved refractory. He then went to the other baſe of the priſm *d e f g h r*, and found, that the edges which admitted ſections ſimilar to the preceding ones were not the edges *e f*, *d r*, *g k*, correſponding with thoſe which had been found diviſible at the oppoſite baſe, but the intermediate edges *d e*, *k r*, *g f*. The trapezium *l q y v* repreſents the ſection of the ſegment, which had *k r* for its vertex. This ſection was evidently parallel to the ſection *p s u t*; and the other four ſections were alſo parallel two and two. Theſe ſections were, without doubt, the natural joinings of the layers of the cryſtal. And he eaſily ſucceeded in making others parallel to them, without its being poſſible for him to divide the cryſtal in any other direction. In this manner he detached layer after layer, approaching always nearer and nearer the axis of the priſm, till at laſt the baſes diſappeared altogether, and the priſm was converted into a ſolid OX (fig. 9.), terminated by twelve pentagons, parallel two and two; of which thoſe at the extremities, that is to ſay, ASRIO, IGEDO, BAODC at one end, and FKNPQ, MNPXU, ZQPXY at the other, were the reſults of mechanical diviſion, and had their common vertices O, P ſituated at the centre of the baſes of the original priſm. The ſix lateral pentagons RSUXY, ZYRIG, &c. were the remains of the ſix ſides of the original priſm.

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 *a e* (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 parallelopiped, 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 Hauy; 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 Hauy, 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 *o n f g* (fig. 15.) will fall exactly on the ſquare marked with the ſame letters in fig. 14.

Above this lamina let us apply a ſecond *l m p u* (fig. 16.),

(c) The explanation of Bergman is not very different. See his *Opuſc.* vol. ii. diff. 1.

Cryſtallization.

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 *v x y z* (fig. 17.) conſiſting only of 9 cubes; ſo that its baſe ſhall reſt upon the letters *v x y z* (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 laminæ 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 laminæ 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 *laminæ of ſuperpoſition* (as the Abbé Hauy calls the laminæ 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 laminæ 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 laminæ, 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 laminæ 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 the 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 *q*, *v*, *k*, *u*, *x*, *y*, *z*, is parallel to the diagonal; as alſo the row *n*, *t*, *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 laminæ 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 laminæ 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 A *a*, B *b*, C *c*, D *d* (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,

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′G′L′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 laminæ 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 laminæ 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 laminæ. The laſt lamina z' (fig. 30.) is a ſingle cube, which ought to be placed upon the ſquare z (fig. 29.).

The laminæ 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 laminæ, 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 laminæ compoſing the triangle L Q C (fig. 31.) is much ſmaller than that of the laminæ 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 Hauy *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 diagonals and the edges. This is the caſe when the ſubtractions are made by ranges of double, triple, &c. moleculæ. Fig. 33. exhibits an inſtance of the ſubtractions in queſtion; and it is ſeen that the moleculæ 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 $a\,b\,c\,d$, $e\,d\,f\,g$, $h\,g\,i\,l$, &c. to reduce this caſe under that of the common decrements on the angles. To this particular kind of decrement Mr Hauy 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, $b\,a\,z\,r$ the ſection of the firſt lamina of ſuperpoſition, $g\,f\,e\,n$ that of the ſecond, &c. Theſe decrements Mr Hauy has called *mixed*.

Theſe two laſt ſpecies of decrements occur but rarely; Mr Hauy found them only in certain metallic ſubſtances.

All the metamorphoſes to which cryſtals are ſubjected depend, according to Mr Hauy, 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 Hauy *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

of

Cryſtallization.

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 Hauy 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 Hauy has found, that the primitive form of all the cryſtals which he has examined may be reduced to ſix; 1. The parallelopipedon 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 Hauy 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.

We

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.

873 Remarks on the chemical nomenclature.

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 corraline 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*."

* Encycl. Method. Chim. Preface.

This nomenclature was adopted by several chemists, and it was used in the greatest part of the first volume 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. It occa-

* See the Journ. de Phys. for 1788, 89, 90, 91, passim.

(D) See his thoughts on a natural history of fossils in the 4th vol. of his *Opusc.*

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 rivalship 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 *Encyclopedia*. 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.

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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 shalt make one cherub at the one end, and the other cherub at the other end: מן הכפרת, out of the mercy-seat (Margin Eng. Traslat. 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.)

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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.) דמות the likeness of four livings creatures or animals; דמות אדם להנה 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, and

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, לחם to them. So there were at leaſt two compound figures. Ver. 10. ‘ And the likeneſs 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 vail of the tabernacle, and on the walls, doors, and vail 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 כרוב is uſed for one compound figure with four faces, and כרובים in the plural for ſeveral ſuch compounds (ſee Exod. xxv. 18, 19. xxxvii. 8. 1 Kings vi. 23—26.), ſo is כרוב 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 כרובים 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.

“ *2dly*, 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.

“ *3dly*, 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,

“ *4thly*, 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,

5thly, When God ‘ raiſed Chriſt (the humanity) from the dead, he ſet him at his own right hand in the heavenly places, far above, ‘ΥΠΕΡΑΝΩ, 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.)

“ *6thly*, The prophet Ezekiel ſaith (ch. x. 20.), ‘ This is the living creature, החיה (which muſt mean one compound figure, comp. ver. 14.) that I ſaw’ תחת inſtead of, a ſubſtitute of ‘ the Aleim of Iſrael. תחת, 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 תחת 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 vail and curtains of the outer tabernacle, and on the vail, 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 vails, 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. x. 20.

x. 20. comp. Matt. xxvii. 51. And as the texts just cited from the New Testament afford us divine anthority 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 מספרים כבוד 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 שמש 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. lx. 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 רוח in Hebrew, and Πνευμα in Greek (both which words in their primary sense denote the material spirit or air in motion), to which appellation the epithet קדש, αγιος 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 Hutchinson 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 paradiſiacal diſpenſation of religion, Jehovah Aleim himſelf ſet up theſe emblems, together with the burning flame המתהפכת 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."

* Ch. v. 8. xix. 4.

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 viſional 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—ישתחו ל proſtrated themſelves to, LXX. προσεκυνησαν; 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, וישתחו 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 of 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.

CHESS, 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 *Cheturanga*, i. e. the four *angá's*, 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*, *chess*, 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."

* *Asiatic Researches*, vol. ii. Mem. 9.

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 *Bhawishya Purán*; in which the form and principal rules of this factitious warefare 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 *Purán*) 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 *angás* 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'h*, or armed *chariot*, which the *Bengalese* pronounce *rot'h*, and which the Persians changed into *rokh*; whence came the *rook* of some European nations; as the *vierge* and *fal* 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 Purán) "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 *Purán* 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 *Purán* 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 *Purán*) 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 by 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 *sinhasana* 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 *sinhasana* 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 chess; 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 *Lanee*, 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 triumviri, 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 evolvitur* (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 cœnacula miles*.

* *De bellis civil.* lib. iv. p. 962. edit. Tollii.

† *Sat.* 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

‡ *Epist.* 64.

(A) Ες καπνωδεις υπωροφια, η των τεγων ταις κεραμισι βυομεναις.

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 *,

'Et jàm summa procul villarum culmina fumant,'

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 *Vespæ* 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 §.'

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 *."

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 bason 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. Anacharsis, the Scythian philosopher, though displeased 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 Heliogabulus caused to be burned in these stoves, instead of wood, Indian spiceries 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."

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 same

* Eclog. i. ver. 83.

† *Aulular*, act ii. sc. 4.

‡ Τηλια.

§ *Horat.* lib. i. sat. 5.

* *Francisci Marii Grapaldi de partibus ædium libri.*

† *Plutarch. Sympos.* lib. vi. 7. p. 692.

‡ *Æl. Lamprid. Vita Heliogab.* cap. 31.

fame fize, which is either filled with burning coals, or a fire of wood and other inflammable fubftances is made in it. When this is done, they place over the hole or ftove a wooden top, like a fmall low table, and fpread above it a large coverlet quilted with cotton, which hangs down on all fides to the floor. This covering condenfes the heat, and caufes it to warm the whole apartment. The people who eat or converfe there, and fome who fleep in it, lie down on the floor above the carpet, and lean, with their fhoulders againft the wall, on fquare cufhions, upon which they fometimes alfo fit; for the *tennor* is conftructed in a place equally diftant from the walls on both fides. Thofe who are not very cold only put their feet under the table or covering; but thofe who require more heat can put their hands under it, or creep under it altogether. By thefe means the ftove diffufes over the whole body, without caufing uneafinefs to the head, fo penetrating and agreeable a warmth, that I never in winter experienced any thing more pleafant. Thofe, however, who require lefs heat let the coverlet hang down on their fide to the floor, and enjoy without any inconvenience from the ftove the moderately heated air of the apartment. They have a method alfo of ftirring up or blowing the fire when neceffary, by means of a fmall pipe united with the tennor or ftove under the earth, and made to project above the floor as high as one choofes; fo that the wind, when a perfon blows into it, becaufe it has no other vent, acts immediately upon the fire like a pair of bellows. When there is no longer occafion to ufe this ftove, both holes are clofed up, that is to fay, the mouth of the ftove and that of the pipe which conveys the air to it, by a flat ftone made for that purpofe. Scarcely any appearance of them is then to be perceived, nor do they occafion inconvenience, efpecially in a country where it is always cuftomary to cover the floor with a carpet, and where the walls are plaftered. In many parts thefe ovens are ufed to cook victuals, by placing kettles over them. They are employed alfo to bake bread; and for this purpofe 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 ftove itfelf."

Our learned author having proved, to our entire fatisfaction, that chimneys, fuch as we have now in every comfortable room, were unknown to the moft polifhed nations of antiquity, fets himfelf to inquire into the era of their invention; and the oldeft account of them which he finds is an infcription 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 fome places they had been in ufe for a confiderable time before that period; for *De Gataris*, in his Hiftory of Padua, relates, that *Francefco de Carraro*, lord of Padua, came to Rome in 1368, and finding no chimneys in the inn where he lodged, becaufe at that time fire was kindled in a hall in the middle of the floor, he caufed two chimneys like thofe which had *long* been ufed at Padua to be conftructed by mafons and carpenters, whom he had brought along with him. Over thefe chimneys, the firft ever feen at Rome, he affixed his arms, which were ftill remaining in the time of De Gataris, who died of the plague in 1405.

Though chimneys have been thus long in ufe, they are yet far enough from being brought to perfection. There is hardly a modern houfe, efpecially if highly finifhed, in which there is not one room at leaft liable to be filled with fmoke when it is attempted to be heated by an open fire; and there are many houfes fo infefted with this plague as to be almoft uninhabitable during the winter months; not to mention other great defects in common chimneys, which not being fo obvious have attracted lefs attention. Many ingenious methods have been propofed to cure fmokey chimneys in every fituation (fee SMOKE, *Encycl.*); but Count Rumford's Effay on this fubject contains the moft valuable directions that we have feen, not only for removing the inconveniency of fmoke, but likewife for increafing the heat of the room by a diminifhed confumption of fuel.

To thofe who are at all acquainted with the nature and properties of elaftic fluids, it muft be obvious, that the whole myftery of curing fmokey chimneys confifts in finding out and removing the accidental caufes which prevent the heated fmoke from being forced up the chimney by the preffure of the cool and therefore heavier air of the room. Though thefe caufes are various, yet, fays our author, that which will moft commonly be found to operate, is the bad conftruction 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 ufe 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 fhould be firft turned in every attempt which is made to improve the conftruction of chimneys; for however perfect a fire-place may be in other refpects, if the opening left for the paffage of the fmoke is larger than is neceffary for that purpofe, nothing can prevent the warm air of the room from efcaping through it; and whenever this happens, there is not only an unneceffary lofs 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 thofe who inhabit it. But although both thefe evils may be effectually remedied by reducing the throat of the chimney to a proper fize, yet in doing this feveral precautions will be neceffary. And firft of all, the throat of the chimney fhould be in its proper place; that is to fay, in that place in which it ought to be, in order that the afcent of the fmoke may be moft facilitated: now as the fmoke and hot vapour which rife 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 circumftance to be attended to in determining the proper place for the throat of a chimney, and that is, to afcertain its diftance 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 confidered, and feveral advantages and difadvantages to be weighed and balanced.

As the fmoke and vapour which afcend from burning fuel rife in confequence of their being rarefied by heat, and made lighter than the air of the furrounding atmofphere; and as the degree of their rarefaction, and confequently their tendency to rife, is in proportion to the intenfity of their heat; and further, as they are hotter-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 ſhally 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 pocker; 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

form

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 thicknefs) is brought up fo high that there remains no more than about ten or eleven inches between what is then the top of it and the infide of the mantle, or lower extremity of the breaft of the chimney, an opening or door-way, eleven or twelve inches wide, muft 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 neceffary to carry up the back, will make the opening abundantly fufficient to let the chimney-fweeper pafs. When the fire-place is finifhed, this door-way is to be clofed by a tile or fit piece of ftone placed in it without mortar, and by means of a rabbit made in the brick-work, confined in its place in fuch a manner as that it may be eafily removed when the chimney is to be fwept, and reftored 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 reprefents the fection of a chimney after it has been properly altered from what is exhibited in fig. 1. In this improved chimney *k l* is the new back of the fire-place; *l i* the tile or ftone which clofes the door-way for the chimney-fweeper; *d i* the throat of the chimney narrowed to four inches; *a* the mantle, and *b* the ftone placed under the mantle, fuppofed to have been too high, in order to diminifh the height of the opening of the fire-place in front.

It has been obferved above, that the new back, which it will always be found neceffary to build in order to bring the fire fufficiently forward, in altering a chimney conftructed on the common principles, need never be thicker than the width of a common brick. The fame may be faid of the thicknefs neceffary to be given to the new fides or covings of the chimney; or if the new back and covings are conftructed of ftone, one inch and three quarters, or two inches in thicknefs, will be fufficient. Care fhould be taken in building up thefe new walls to unite the back to the covings in a folid manner.

Whether the new back and covings are conftructed of ftone or built of bricks, the fpace between them and the old back and covings of the chimney ought to be filled up, to give greater folidity to the ftructure. This may be done with loofe rubbifh, or pieces of broken bricks or ftones, provided the work be ftrengthened by a few layers or courfes of bricks laid in mortar; but it will be indifpenfably neceffary to finifh the work where thefe new walls end, that is to fay, at the top of the throat of the chimney, where it ends abruptly in the open canal of the chimney, by a horizontal courfe of bricks well fecured with mortar. This courfe of bricks will be upon a level with the top of the door-way left for the chimney-fweeper; and the void behind the doorway muft be covered with a horizontal ftone or tile, to be removed at the fame time the door is removed, and for the fame purpofe.

From thefe defcriptions it is clear, that where the throat of the chimney has an end, that is to fay, where it enters into the lower part of the open canal of the chimney, *there* the three walls which form the two covings and the back of the fire-place all end abruptly. It is of much importance that they fhould end in this manner; for were they to be floped outward, and raifed in fuch a manner as to fwell out the upper extremity of the throat of the chimney in the form of a trumpet, and increafe it by degrees to the fize of the canal of the chimney, this manner of uniting the lower extremity of the canal of the chimney with the throat would tend to affift the winds, which may attempt to blow down the chimney, in forcing their way through the throat, and throwing the fmoke backward into the room; but when the throat of the chimney ends abruptly, and the ends of the new walls form a flat horizontal furface, it will be much more difficult for any wind from above to find and force its way through the narrow paffage of the throat of the chimney.

As the two walls which form the new covings of the chimney are not parallel to each other, but inclined, prefenting an oblique furface 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 fection of the throat will not be an oblong fquare; but its deviation from that form is a matter of no confequence; and no attempts fhould ever be made, by twifting the covings above where they approach the breaft of the chimney, to bring it to that form. All twifts, bends, prominences, excavations, and other irregularities of form in the covings of a chimney, never fail to produce eddies in the current of air which is continually paffing into, and through, an open fire-place in which a fire is burning; and all fuch eddies difturb either the fire or the afcending current of fmoke, or both; and not unfrequently caufe the fmoke to be thrown back into the room. Hence it appears, that the covings of chimneys fhould never be made circular, or in the form of any other curve, but always quite flat.

For the fame reafon, that is to fay, to prevent eddies, the breaft of the chimney, which forms that fide of the throat that is in front or neareft to the room, fhould be neatly cleaned off, and its furface made quite regular and fmooth. This may be eafily done by covering it with a coat of plafter, which may be made thicker or thinner in different parts, as may be neceffary in order to bring the breaft of the chimney to be of the proper form.

With regard to the form of the breaft of a chimney, this is a matter of very great importance, and which ought always to be particularly attended to. The worft form it can have is that of a vertical plane or upright flat; and next to this the worft form is an inclined plane. Both thefe forms caufe the current of warm air from the room, which will, in fpite of every precaution, fometimes find its way into the chimney, to crofs upon the current of fmoke which rifes from the fire in a manner moft likely to embarrafs it in its afcent, and drive it back.

The current of air which, paffing under the mantle, gets into the chimney, fhould be made *gradually to bend its courfe upwards*; by which means it will unite *quietly* with the afcending current of fmoke, and will be lefs likely to check it, or force it back into the room. Now this may be effected with the greateft eafe and certainty, merely by *rounding off* the breaft of the chimney or back part of the mantle, inftead of leaving it flat or full of holes and corners; and this of courfe ought always to be done.

Having thus afcertained the form and pofition of the new covings, the ingenious author next turns his attention to the height to which they fhould be carried. This will depend not only on the height of the mantle, but

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 covings 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 covings 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 covings.

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 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 covings 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 h* parallel to the line A B, and this line *g h* 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 h*, 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.

not more than two or three inches greater than *three times* the width of the new back of the chimney (*i k*), 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 A B, *c a* and *c b* muſt be ſet off equal to the width of the back (*i k*), added to half its width (*f i*); 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 *a* A and *b* B 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 *b c* 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 ſemicircular 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 *c A*, which they ought to do,—but in the line *c o*, 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 *d c 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 spunge, or other elastic substance as the occasion may require.

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.

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 Pekin 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 Grosier 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 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 *Brahmans*, 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.

* *Asiatic Researches*, vol. ii. mem. 25.

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 Menu the

China.

the son 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 *Pahlavas*, 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 *Lún Yú*, 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 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 fasts 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 consanguity, especially as the Hindoos have preserved their old language and ritual, while the Chinese very soon lost both; and the Hindoos have constantly

China. 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 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 antidated; 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 the

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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 Budha, 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 Brahams, 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.

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founds of B, D, R, and X, for inftance, he fubftitutes fome other founds to which the fame organ has been accuftomed; L for R, and, as we have reafon to think from fome expreffions of Sir William Jones's, F for B. The nice diftinctions between the tones and accents of words nearly refembling each other in found, but varying much in fenfe, require a nicety of ear to diftinguifh, and of vocal powers to render them exactly. Synonymous words are therefore frequently introduced in Chinefe dialogue to prevent any doubt about the intended fenfe; and if in an intricate difcuffion any uncertainty fhould ftill remain as to the meaning of a particular expreffion, recourfe is had to the ultimate criterion of tracing with the finger in the air, or otherwife, the form of the character, and thus afcertaining at once which was meant to be expreffed. In a Chinefe fentence there is no marked diftinction of fubftantives, adjectives, or verbs; nor any accordance of gender, number, and cafe. A very few particles denote the paft, the prefent, and the future; nor are thofe auxiliaries employed when the intended time may be otherwife inferred with certainty. A Chinefe who means to declare his intention of departing to-morrow, never fays that he *will* depart to-morrow; becaufe the expreffion of the morrow is fufficient to afcertain that his departure muft be future. The plural number is marked by the addition of a word, without which the fingular always is implied. Neither the memory nor the organs of fpeech are burthened with the pronunciation of more founds to exprefs ideas than are abfolutely neceffary to mark their difference. The language is entirely monofyllabic. A fingle fyllable always expreffes a complete idea. Each fyllable may be founded by an European confonant preceding a vowel, fometimes followed by a liquid. Such an order of words prevents the harfhnefs of fucceeding confonants founding ill together; and renders the language as foft and harmonious as the Italian is felt to be, from the rarity of confonants, and the frequency of its vowel terminations.

"The names or founds, by which men may be firft fuppofed to have diftinguifhed other animals, when occafion offered to defignate them in their abfence, were attempts at an imitation of the founds peculiar to thofe beings; and ftill, in Chinefe, the name, for example, of a cat, is a pretty near refemblance of its ufual cry. It occurred as naturally to endeavour, in fpeaking, to imitate the voice, if practicable, as it was in writing to fketch a rude figure of the object of defcription. It is obfervable, that the radical words of moft languages, feparated from the fervile letters which mark their inflections, according to their conjugations or declenfions, are monofyllabic. A part of each radical word is retained in compofition to denote the meaning and etymology of the compound, which thus becomes polyfyllabic; but the Chinefe grammarians, aware of the inconvenience refulting from the length and complication of founds, confined all their words, however fignificant of combined ideas, to fingle founds; and retained only in writing, fome part at leaft of the form of each character denoting a fimple idea, in the compound characters conveying complex ideas."

This is a very plaufible, and perhaps the true, account of the monofyllabic form of the Chinefe language; but it is proper to ftate the different account which is given of this peculiarity by Sir William Jones. "It has arifen, according to him, from the fingular habits of the people; for though their common tongue be fo *mufically* accented as to form a kind of recitative, yet it wants thofe *grammatical* accents without which all human tongues would appear monofyllabic. Thus *Amita*, with an accent on the firft fyllable, means, in the *Sanfcrit* language, *immeafurable*, and the natives of Bengal pronounce it *Omito;* but when the religion of BUDDHA, the fon of Máyá, was carried into *China*, the people of that country, unable to pronounce the name of their new god, called him FOE, the fon of MO-YE; and divided his epithet *Amita* into three fyllables O-MI-TO, annexing to them certain ideas of their own, and expreffing them in writing by three diftinct fymbols. Hence it is that they have clipped their language into monofyllables, even when the ideas expreffed by them, and the written fymbols for thofe ideas, are very complex."

"In the Chinefe language Sir George Staunton informs us, that there is a certain order, or fettled fyntax, in the fucceffion of words in the fame fentence; a fucceffion fixed by cuftom, differently in different languages, but founded on no rule or natural order of ideas, as has been fometimes fuppofed; for though a fentence confifts of feveral ideas, to be rendered by feveral words, thefe ideas all exift and are connected together in the fame inftant; forming a picture or image, every part of which is conceived at once. The formation of Chinefe fentences is often the fimpleft and moft artlefs poffible, and fuch as may naturally have occurred at the origin of fociety. To interrogate, for example, is often at leaft to require the folution of a queftion, whether the fubject of doubt be in a particular way or the contrary; and accordingly a Chinefe inquiring about his friends health, will fometimes fay, *hou, poo hou?* The literal meaning of which words is, "well, not well?" A fimple character repeated ftands fometimes for more than one of the objects which fingly it denotes, and fometimes for a collective quantity of the fame thing. The character of *moo* fingly is a tree, repeated is a thicket, and tripled is a foreft.

"In Chinefe there are fcarcely fifteen hundred diftinct founds. In the written language there are at leaft eighty thoufand characters or different forms of letters, which number divided by the firft gives nearly fifty fenfes or characters upon an average to every found expreffed; a difproportion, however, that gives more the appearance than the reality of equivocation and uncertainty to the oral language of the Chinefe.

"The characters of the Chinefe language were originally traced, in moft inftances, with a view to exprefs either real images, or the allegorical figns of ideas: a circle, for example, for the fun, and a crefcent for the moon. A man was reprefented by an erect figure, with lines to mark the extremities. It was evident that the difficulty and tedioufnefs of imitation will have occafioned foon a change to traits more fimple 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 refemblance, in fome few inftances, ftill remains of the original forms in the prefent hieroglyphic characters; and the gradation of their changes is traced in feveral Chinefe books. Not above half a dozen of the prefent characters confift each of a fingle line; but moft of of them confift of many, and a few of fo many as feventy different ftrokes. The form of thofe characters has not been fo flux as the found of words, as appears in the inftance of almoft all the countries bordering on the Chinefe Sea or Eaftern Afia, where the Chinefe written, but not the oral language, is underftood; in like manner, as one form of Arabic figures to denote numbers, and one fet of notes for mufic, are uniform and intelligible throughout Europe, notwithftanding the variety of its languages.

" A certain order or connection is to be perceived in the arrangement of the written characters of the Chinefe; as if it had been formed originally upon a fyftem to take place at once, and not grown up, as other languages, by flow and diftant intervals. Upwards of two hundred characters, generally confifting each of a few lines or ftrokes, are made to mark the principal objects of nature, fomewhat in the manner of Bifhop Wilkin's divifions, in his ingenious book on the fubject of univerfal language, or real character. Thefe may be confidered as the genera or roots of language, in which every other word or fpecies, in a fyftematic fenfe, is referred to its proper genus. The heart is a genus, of which the reprefentation of a curve line approaches fomewhat to the form of the object; and the fpecies referable to it include all the fentiments, paffions, and affections, that agitate the human breaft. Each fpecies is accompanied by fome mark denoting the genus or heart. Under the genus *hand* are arranged moft trades and manual exercifes. Under the genus *word* every fort of fpeech, ftudy, writing, underftanding, and debate. A horizontal line marks a unit; croffed by another line it ftands for ten, as it does in every nation which repeats the units after that number. The five elements, of which the Chinefe fuppofe all bodies in nature to be compounded, form fo many genera, each of which comprehends a great number of fpecies under it. As in every compound character or fpecies, the abridged mark of the genus is difcernible by a ftudent of that language, in a little time he is enabled to confult the Chinefe dictionary, in which the compound characters or fpecies are arranged under their proper genera. The characters of thefe genera are placed at the beginning of the dictionary, in an order which, like that of the alphabet, is invariable, and foon becomes familiar to the learner. The fpecies under each genus follow each other, according to the number of ftrokes of which each confifts, independently of the one or few which ferve to point out the genus. The fpecies wanted is thus foon found out. Its meaning and pronunciation are given through other words in common ufe; the firft of which denotes its fignification and the other its found. When no one common word is found to render exactly the fame found, it is communicated by two words with marks, to inform the inquirer that the confonant of the firft word and the vowel of the fecond joined together form the precife found wanted.

" The compofition of many of the Chinefe characters often difplays confiderable ingenuity, and ferves alfo to give an infight into the opinions and manners of the people. The character expreffive of happinefs includes abridged marks of land, the fource of their phyfical, and of children that of their moral, enjoyments. This character, embellifhed in a variety of ways, is hung up almoft in every houfe. Sometimes written by the hand of the emperor, it is fent by him as a compliment, which is very highly prized, and fuch as he was pleafed to fend to the embaffador.

" Upon the formation, changes, and allufions of compound characters, the Chinefe have publifhed many thoufand volumes of philological learning. Nowhere does criticifm more abound, or is more ftrict. The introduction or alteration of a character is a ferious undertaking, and feldom fails to meet with oppofition. The moft ancient writings of the Chinefe are ftill claffical amongft them. The language feems in no inftance to have been derived from or mixed with any other. The written feems to have followed the oral language foon after the men who fpoke it were formed into a regular fociety. Though it is likely that all hieroglyphical languages were originally founded on the principles of imitation, yet in the gradual progrefs towards arbitrary forms and founds, it is probable that every fociety deviated from the originals in a different manner from the others; and thus for every independent fociety there arofe a feparate hieroglyphic language. As foon as a communication took place between any two of them, each would hear names and founds not common to both; each reciprocally would mark down fuch names in the founds of its own characters, bearing, as hieroglyphics, a different fenfe. In that inftance, confequently, thofe characters ceafe to be hieroglyphics, and were merely marks of found. If the foreign founds could not be expreffed but by the ufe of a part of two hieroglyphics, in the manner mentioned to be ufed fometimes in Chinefe dictionaries, the two marks joined together become in fact a fyllable. If a frequent intercourfe fhould take place between communities fpeaking different languages, the neceffity of ufing hieroglyphics merely as marks of found would frequently recur. The practice would lead imperceptibly to the difcovery that, with a few hieroglyphics, every found of the foreign language might be expreffed; and the hieroglyphics which anfwered beft this purpofe, either as to exactnefs of found or fimplicity of form, would be felected for this particular ufe; and ferving as fo many letters, would form in fact together what is called an alphabet. Thus, the paffage from hieroglyphic to alphabetic writing may naturally be traced, without the neceffity of having ' recourfe to divine inftruction, as fome learned men have conjectured, on the ground that the art of writing by an alphabet is too refined and artificial for untutored reafon.'

" The Chinefe printed character is the fame as is ufed in moft manufcripts, and is chiefly formed of ftraight lines in angular pofitions, as moft letters are in Eaftern tongues, efpecially the Sanfcrit; the characters of which, in fome inftances, admit of additions to their original form, producing a modification of the fenfe. A running hand is ufed by the Chinefe only on trivial occafions, or for private notes, or for the eafe and expedition of the writer; and differs from the other as much as an European manufcript 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 ftudy of Chinefe writings arifes from the general exclufion of the auxiliary particles of colloquial language, that fix the relation between indeclinable words, fuch as are all thofe of the Chinefe language. The judgment muft be conftantly exercifed

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exercifed by the ftudent, to fupply the abfence of fuch affiftance. That judgment muft be guided by attention to the manners, cuftoms, laws, and opinions of the Chinefe, and to the events and local circumftances of the country, to which the allufions of language perpetually refer. If it in general be true, that a language is difficult to be underftood in proportion to the diftance of the country where it is fpoken, and that of him who endeavours to acquire it, becaufe in that proportion the allufions to which language has continually recourfe are lefs known to the learner, fome idea may be conceived of the obftacles which an European may expect to meet in reading Chinefe, not only from the remotenefs of fituation, but from the difference between him and the native of China in all other refpects. The Chinefe characters are in fact fketches or abridged figures, and a fentence is often a ftring of metaphors. The different relations of life are not marked by arbitrary founds, fimply conveying the idea of fuch connection; but the qualities naturally expected to arife out of fuch relations become frequently the name by which they are refpectively known. Kindred, for example, of every degree is thus diftinguifhed with a minutenefsunknown in other languages. That of China has diftinct characters for every modification known by them of objects in the phyfical and intellectual world. Abftract terms are no otherwife expreffed by the Chinefe than by applying to each the name of the moft prominent objects to which it might be applied, which is likewife indeed generally the cafe of other languages. Among the Latins the abftract idea of virtue, for example, was expreffed under the name of valour or ftrength (*virtus*), being the quality moft efteemed among them, as filial piety is confidered to be in China. The words of an alphabetic language being formed of different combinations of letters or elemental parts, each with a diftinct found and name, whoever knows and combines thefe together, may read the words without the leaft knowledge of their meaning; not fo hieroglyphic language, in which each character has indeed a found annexed to it, but which bears no certain relation to the unnamed lines or ftrokes of which it is compofed. Such character is ftudied and beft learned by becoming acquainted with the idea attached to it; and a dictionary of hieroglyphics is lefs a vocabulary of the terms of one language with the correfpondent terms in another, than an encyclopædia containing explanations of the ideas themfelves reprefented by fuch hieroglyphics. In fuch fenfe only can the acquifition of Chinefe words be juftly faid to engrofs moft of the time of men of learning among them. The knowledge of the fciences of the Chinefe, however imperfect, and of their moft extenfive literature, is certainly fufficient 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 muft depend on capacity and opportunity."

Next to the fingular ftructure of the oral and written language of the Chinefe, there is perhaps nothing in their hiftory more furprifing to a native of Europe than the number of the people, and the means by which they contrive to procure fubfiftence, without foreign trade, in a country fo crouded, and at the fame time not everywhere of a fertile foil. In the Encyclopædia, the population of this vaft empire is ftated, from M. Grofier, at 200 millions: but great as this is, when compared with the population of every other extenfive country, it appears to be far fhort of the truth. Sir George Staunton has publifhed a ftatement, taken from one of the public offices in the capital, and given by a great and refpectable manderin to Lord Macartney, in which it is fhewn that China Proper contains not fewer than 333 millions of inhabitants. As the extent of the country is 1,297,999 fquare miles, there are of courfe very near 260 inhabitants to every fquare mile; and of thefe miles a very confiderable proportion confifts of nothing but barren rocks. That this account is accurate there can be little doubt; for the extent of the provinces was afcertained by aftronomical obfervations, as well as by admeafurement; and the number of individuals is regularly taken in each divifion of a diftrict by a tythingman, or every tenth mafter of a family. Thefe returns are collected by officers refident fo near as to be capable of correcting any grofs miftake, and are all lodged in the great regifter of Pekin.

For this exceffive population our author fatisfactorily accounts. Celibacy, fays he, is rare in China, even in the military profeffion; the marriages are prolific as well as early, and the influence of the patriarchal fyftem, to be explained afterwards, is fuch, that a man's children adds to his wealth. It is reckoned a difcredit to be without offspring; and they who have none adopt others, who become theirs exclufively. In cafe of marriage, fhould a wife prove barren, a fecond may be efpoufed in the lifetime of the firft. The opulent, as in moft parts of the Eaft, are allowed, without reproach, to keep concubines, of whom the children are confidered as being thofe of the legitimate wife, and partake in all the rights of legitimacy. "Accidents fometimes of extraordinary drought, and fometimes of exceffive inundations, occafionally produce famine in particular provinces, and famine difeafe; but there are few drains from moral caufes either of emigration or foreign navigation. The number of manufactures, whofe occupations are not always favourable to health, whofe conftant confinement to particular fpots, and fometimes in a clofe or tainted atmofphere, muft be injurious, and whofe refidence in towns expofes them to irregularities, bears but a very fmall proportion to that of hufbandmen in China. In general there feems to be no other bounds to Chinefe populoufnefs than thofe which the neceffity of fubfiftence may put to it. Thefe boundaries are certainly more enlarged than in other countries. The whole furface of the empire is, with trifling exceptions, dedicated to the production of food for man alone. There is no meadow, and very little pafture; nor are fields cultivated in oats, beans, or turnips, for the fupport of cattle of any kind. Few parks or pleafure grounds are feen, excepting thofe 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 fuffered to lie wafte by the neglect, or the caprice, or for the fport of great proprietors. No arable land lies fallow. The foil, under a hot and fertilizing fun, yields annually, in moft inftances, double crops, in confequence of adapting the culture to the foil, and of fupplying its defects by mixture with other earths, by manure, by irrigation, by careful and judicious induftry of every kind. The labour of man is little diverted from that induftry

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to minifter to the luxuries of the opulent and powerful, or in employments of no real ufe. Even the foldiers of the Chinefe army, except during the fhort intervals of the guards which they are called to mount, or the exercifes, or other occafional fervices which they perform, are moftly employed in agriculture. The quantity of fubfiftence is increafed alfo, by converting more fpecies of animals and vegetables to that purpofe than is ufual in other countries. And even in the preparation of their food the Chinefe have economy and management."

The government of China is defpotic; and it is a curious fpectacle to behold fo large a proportion of the whole human race, connected together in one great fyftem of polity, fubmitting quietly, and through fo confiderable an extent of country, to one great fovereign; and uniform in their laws, their manners, and their language, but differing effentially in each of thefe refpects from every other portion of mankind: and neither defirous of communicating with nor forming any defigns againft the reft of the world. To produce fuch a phenomenon, many caufes muft be combined; but perhaps the principal are to be found in the patriarchal fyftem already mentioned, in the laws and cuftoms of the empire, and in the belief that the emperor is the vicegerent of heaven, and guided in all his actions by divine infpiration.

The patriarchal fyftem is founded upon that filial piety which the philofophers of China have uniformly reprefented as the greateft of human virtues. Thefe fages, while they fuccefsfully inculcated this duty, have left parental affection to its own natural influence; and hence in China parents are lefs frequently neglected than infants are expofed. The laws of the empire, to corroborate the difpofition to filial obedience, furnifh an opportunity for punifhing 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 faid, is a meafure of prudence; becaufe the children, particularly the fons, are bound to maintain their parents.

A Chinefe dwelling is generally furrounded by a wall fix or feven feet high. Within this inclofure a whole family, of three generations, with all their refpective wives and children, will frequently be found. One fmall room is made to ferve for the individuals of each branch of the family, fleeping in different beds, divided only by mats hanging from the ceiling. One common room is ufed for eating.

The prevalence of this cuftom, of retaining the feveral branches of a family under the fame 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 fubfift, like foldiers in a mefs, with more economy and advantage. As the venerable patriarch of each habitation prefides over his defcendants with the authority of a magiftrate; fo the different orders of magiftrates are, in their different diftricts 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 lefs inequality in the fortunes than in the conditions of men. The ancient annals of the empire teftify, that for a long period of time, the earth, like the other elements of nature, was enjoyed by its inhabitants almoft in common. Their country was divided into fmall equal diftricts; every diftrict was cultivated conjointly by eight labouring families, which compofed each hamlet; and they enjoyed all the profit of their labours, except a certain fhare of the produce referved for public expences. It is true, indeed, that after a revolution, deplored in all the Chinefe hiftories, which happened prior to the Chriftian era, the ufurper granted all the lands away to the partners of his victories, leaving to the cultivators of the foil a fmall pittance only out of the revenue which it yielded. Property in land alfo became hereditary: but in procefs of time, the moft confiderable domains were fubdivided into very moderate parcels by the fucceffive diftribution of the poffeffions of every father equally among all his fons; the daughters being always married without dower. It very rarely happened that there was but an only fon to enjoy the whole property of his deceafed parents; and it could fcarcely be increafed by collateral fucceffion.

From the operations of all thofe caufes, there was a conftant tendency to level wealth; and few could fucceed to fuch an accumulation of it as to render them independent of any efforts of their own for its increafe. Befides, wealth alone confers in China but little importance, and no power; nor is property, without office, always perfectly fecure. 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 lefs objects of temptation. And it is a common remark among the Chinefe, that fortunes, either by being parcelled out to many heirs, or by being loft in commercial fpeculations, gaming, or extravagance, or extorted by oppreffive mandarines, feldom continue to be confiderable in the individuals of the fame family beyond the third generation. To afcend again the ladder of ambition, it is neceffary, by long and laborious ftudy, to excel in the learning of the country, which alone qualifies for public employments.

There are properly but three claffes 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 higheft degree of literature upon thofe who, in public examinations, are found moft able in the fciences of morality and government as taught in the ancient Chinefe writers; with which ftudies the hiftory of their country is intimately blended. Among fuch graduates all the civil offices in the ftate are diftributed by the emperor; and they compofe all the great tribunals of the empire. The candidates for thofe degrees are fuch as have fucceeded in fimilar examinations in the principal city of each province. Thofe who have been chofen in the cities of the fecond order, or chief town of every diftrict in the province, are the candidates in the provincial capital. They who fail in the firft and fecond claffes have ftill a claim on fubordinate offices, proportioned to the clafs in which they had fucceeded. Thofe examinations are carried on with great folemnity, and apparent fairnefs. Military rank is likewife given to thofe who are found upon competition to excel in the military art, and in warlike exercifes. This diftribution

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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 Pekin. 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 sightly. 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 Pekin. 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 he 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.

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 alter 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 *Yuen-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 ſurpriſe 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-hal* 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."

That the awful impreſſion meant to be made upon the

(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, ſurrounded 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 mandarines 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 houſhold 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 ſuperintendant 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 gun-powder 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 indelicacy 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. China, Chineſe.

"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, perpaps, 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

racters

Chineſe. racters engraven on the upper ſurface. They advance in a regular decimal progreſſion, of which Coquebert has diſcovered four diſtinct ſeries, the units of which are in the proportion of 1, 10, 100, 1000. Inſtead of employing a combination of one, two, four, and eight units, or after the new ſyſtem of one, two, and five units, the Chineſe have a diſtinct weight for every intermediate number between one and ten. Thus they have weights of 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 20, 30, 40, 50, 60, 70, 80, 90, &c. Of courſe, thoſe weights which ſtand related to each other in the proportion of 6 to 7, 7 to 8, 8 to 9, 9 to 10, differ ſo little in ſize, that it would be impoſſible to diſtinguiſh them without the help of the characters which are engraven upon the face. This is confeſſedly a defect in the ſyſtem. Of the four different ſeries exhibited to the ſociety, the higheſt bears in China the name of *kin*, and is nearly of equal value with a pound avoirdupois. The kin contains ten times the number of units of the next inferior weight, which the Chineſe denominate *leang* or *loam*, and which the Europeans call *tael*, *taille*, or Chineſe *ounce*. This ounce is divided into ten *tſien*, which anſwers nearly to our drachm. The tſien is again ſubdivided into ten *fen*. The Chineſe extend the decimal ſubdiviſion of their weights conſiderably farther. They have diſtinct names, which are all monoſyllabic, for nine ſeries below the fen. Suppoſing the kin to ſtand for unity, they have,

1,	0	0	0	0	0	0	0	0	0	0	0	0
kin,	leang	tſien	fen	li	hav	ſen	tchin	yai	miao	mo	tſun	ſun

The Chineſe weights, compared with the greateſt preciſion, and with the help of the beſt inſtruments, bear the following proportion to our weights: The kin is equal to 1 pound 12 ounces 2 drachms 24 grains; the leang 1 ounce 1 drachm 60 grains; the tſien 70 grains $\frac{8}{10}$; the fen 7 grains $\frac{8}{100}$. Conſequently the laſt of this ſeries, the ſun, amounts to no more than 0 grains 0000000708.

Chinese Wheel is an engine employed in the province of *Kiang-ſee*, and probably through the whole empire, for raiſing water from rivers to irrigate plantations of ſugar canes, on a ſandy ſoil, conſiderably elevated above the level of the river. By Sir George Staunton, who ſays that it is ingenious in its contrivance, cheap in its materials, eaſy in its operation, and effectual to its purpoſe, it is thus deſcribed:

"Two hard wood-poſts or uprights are firmly fixed in the bed of the river, in a line perpendicular to its bank. Theſe poſts ſupport the axis, about ten feet in length, of a large and durable wheel, conſiſting of two unequal rims, the diameter of one of which, cloſeſt to the bank, being about fifteen inches ſhorter than that of the outer rim; but both dipping in the ſtream, while the oppoſite ſegment of the wheel riſes above the elevated bank. This double wheel is connected with the axis, and is ſupported by 16 or 18 ſpokes obliquely inſerted near each extremity of the axis, and croſſing each other at about two-thirds of their length. They are there ſtrengthened by a concentric circle, and faſtened afterwards to the rims: the ſpokes inſerted in the interior extremity of the axis reaching the outer rim, and thoſe proceeding from the exterior extremity of the ſame axis, reaching the inner and ſmaller rim. Between the rims and the croſſing of the ſpokes is woven a kind of cloſe baſket-work, ſerving as laddle-boards or floats, which meeting ſucceſſively the current of the ſtream, obey its impulſe, and turn round the wheel. To both its rims are attached ſmall tubes or ſpouts of wood, with an inclination of about 25 degrees to the horizon, or to the axis of the wheel. The tubes are cloſed at their outer extremity, and open at the oppoſite end. By this poſition the tubes, which happen in the motion of the wheel to be in the ſtream with their mouths or open ends uppermoſt, fill with water. As that ſegment of the wheel riſes, the mouths of the tubes attach to it, alter their relative inclination, but not ſo much as to let their contents flow out till ſuch ſegment of the wheel becomes the top. The mouths of thoſe tubes are then relatively depreſſed, and pour the water into a wide trough placed on poſts, from whence it is conveyed as may be wanted among the canes.

"The only materials employed in the conſtruction of this water-wheel, except the nave or axis, and the poſts on which it reſts, are afforded by the bamboo. The rims, the ſpokes, the laddle-boards or floats, and the tubes or ſpouts, and even the cords, are made of entire lengths, or ſingle joints, or large pieces, or thin ſlices, of the bamboo. Neither nails, nor pins, nor ſcrews, nor any kind of metal, enters into its conſtruction. The parts are bound together firmly by cordage, alſo of ſlit bamboo. Thus, at a very trifling expence, is conſtructed a machine which, without labour or attendance, will furniſh, from a conſiderable depth, a reſervoir with a conſtant ſupply of water adequate to every agricultural purpoſe.

"Theſe wheels are from 20 to 40 feet in diameter, according to the height of the bank and conſequent elevation to which the water is to be raiſed. Such a wheel is capable of ſuſtaining with eaſe 20 tubes or ſpouts, of the length of four feet, and diameter two inches in the clear. The contents of ſuch a tube would be equal to ſix-tenths of a gallon, and a periphery of 20 tubes, twelve gallons. A ſtream of a moderate velocity would be ſufficient to turn the wheel at the rate of four revolutions in one minute, by which would be lifted 48 gallons of water in that ſhort period; in one hour, 2880 gallons; and 69120 gallons, or upwards of 300 tons of water, in a day."

Sir George, who ſaw this wheel in motion, thinks it preferable in many reſpects to any machine yet in uſe for ſimilar purpoſes. He obſerves, that, while it approaches near to the Perſian wheel, of which a deſcription and figure is given in the article Hydrostatics, *Encycl.* it is more ſimple than that wheel in its contrivance, and much leſs expenſive. This is indeed true; but the ſimpleſt engine of the kind, and therefore the beſt that has yet been invented, is perhaps that which is employed to throw water into the moſs of Blair Drummond in Perthſhire. See Moss, *Encycl.*

Chineſe, Chopine.

CHOPINE, Choppine, or *Chopeene*, a high ſhoe, or rather clog, worn 200 years ago by the Italians.

Tom Coryat, in his Crudities 1611. p. 262, calls them *chapineys*, and gives the following account of them: "There is one thing uſed of the Venetian women, and ſome others dwelling in the cities and towns ſubject to the ſigniory of Venice, that is not to be obſerved, I thinke, amongſt any other women in Chriſtendome, which is ſo common in Venice, that no women whatſoever goeth without it, either in her houſe or abroad, *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 pitty 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 widowes 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 baptised, 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 *chrisom*, 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 chrisom 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 *chrisom* and other accustomed offerings. If the child died before its mother was churched, the *chrisom* was not given to the priest, but employed as a shroud, in which the body was buried; and hence it is that chrisoms are now enumerated, most absurdly indeed, in the weekly bills of mortality. We say absurdly; because children who die unbaptized are called *chrisoms*, though the chrisom, 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, equinoxes,* 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

The

Church.

1 The Greek 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.

4 Invocation of saints.

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."

5 Prayers for the dead.

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

* *Math.* xxv. 19, 20, —31—34. 2 *Tim.* i. 18. 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.

pray for his departed ſriends. 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 cloathed, 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, *myſteries*, 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 baptiſed: 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.

10 Intricate and tedious.

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.

11 Begins in the evening.

The ſervice of every day, whether it has a vigil or not, begins in the evening of what we would call the 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-veſpers*, 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 meſonyecticon*, 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-veſpers* 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 *veſpers*, and the *after-veſpers* making one; the *meſonyecticon*, 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

choir chaunts "Lord have mercy upon us," thirty, forty, or fifty times, ſucceſſively.

Though the number of ſervices is the ſame every day, the ſervices themſelves are conſtantly varying in ſome particular or other, as there is not a day which, in the Greek church, is not either a faſt or a feſtival. Beſides the ſaints, whoſe feſtivals are marked in the calendar, and who are ſo very numerous that there are more than one for every day in the year, there are other ſaints and feſtivals, to which ſome portion of the ſervice for every day of the week is appropriated. Thus, Sunday is dedicated to the reſurrection: Monday, to the angels; Tueſday, to St John Baptiſt; Wedneſday, to the Virgin and the croſs; Thurſday, to the apoſtles; Friday, to the paſſion of Chriſt; and Saturday, to the ſaints and martyrs. For theſe days there are particular hymns and ſervices, in two volumes folio, to which there is a ſupplement containing ſervices for the ſaints and feſtivals, as they occur in the calendar throughout the year. Theſe different ſervices are mixed together, and adjuſted by the directions contained in the book of *regulation*; and it is the difficulty of this adjuſtment which makes the public worſhip of the Greek church ſo very intricate, that, as was ſaid of the ſervice of the Engliſh church before the Reformation, "there is more buſineſs to find out what ſhould be read, than to read it when found out."

12 Mode of adminiſtering baptiſm.

We have obſerved, that the Greeks have no peculiar opinions reſpecting the nature of baptiſm; but the rites and ceremonies with which that ordinance is adminiſtered will appear to our unlearned readers very extraordinary. On the day that a woman is delivered, the prieſt goes to the houſe, and uſes a form of prayer for her and for the child. On the eighth day the child ſhould be regularly carried to the church, where the prieſt having ſigned it with the ſign of the croſs on the forehead, on the mouth, and on the breaſt, offers up for it a prayer, in which he firſt gives it a name, commonly the name of the ſaint for that day in the calendar; he then takes it from the midwife, and ſtanding before the picture of the bleſſed Virgin, he makes the ſign of the croſs with the infant, uttering a kind of hymn in honour of the Virgin and of Simeon, who held in his boſom the Saviour of our ſouls. He then diſmiſſes the company with an exhortation not to delay the baptiſing of the infant, ſhould it appear in danger of death before the regular time for its baptiſm.

On the fortieth day after her delivery, the mother ſhould attend the church to be purified, and carry the child again to be preſented, the perſon who is to be ſponſor being preſent. Upon their arrival at the church door, the prieſt utters ſome pious exclamations; and then, the mother holding the child in her arms and bowing down her head, he makes the ſign of the croſs upon her and the child, and laying his hand upon its head, he prays that the woman may be cleanſed from every ſin and from every defilement, and that the child may be ſanctified and endued with underſtanding, with wiſdom, and with gentleneſs of manners. He then ſigns it again, and again prays for it, for its parents, and for its ſponſor; after which, if it has been privately baptiſed, he takes it in his arms, and makes with it the ſign of the croſs before the door of the church, ſaying, "N. N. the ſervant of God, enters into the church, 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." He then carries the child into the church, ſaying, "he ſhall go into thine houſe, and ſhall worſhip toward thy holy temple;" and advancing into the middle of the church, he ſays, "In the midſt of thy church ſhall he praiſe thee." Then, if the child be a boy, he carries him within the rails of the altar; but if a girl, only to the door, and ſays "*Nunc dimittis* (D);" after which he delivers it to the ſponſor, who makes three reverences, and retires.

This is called the preſentation of the child in the temple, and can only be performed after it has been baptized. In the detail we have given, we have ſuppoſed that it was baptized privately before the purification of the mother, which is now indeed commonly the caſe. Such baptiſm, however, is not regular, being allowed only in caſes of neceſſity; and when it has not taken place, the mother and child are diſmiſſed as ſoon as ſhe is purified, and return at ſome other time, not fixed, in order that the child may be publicly baptized.

Previous to baptiſm, the child, though not two months old, muſt be ſolemnly initiated into the church as a catechumen (See CATECHUMEN, *Encycl.*) By thoſe whoſe religion is a reaſonable ſervice, ſuch initiation of an infant will be conſidered as a very idle ceremony; and the rites with which it is performed are not well calculated to give it even a fictitious importance. At the door of the church the prieſt unties the girdle of the infant; takes off all his clothes but one looſe garment; turns him towards the eaſt, with his head uncovered, his feet naked, and his hands held down; blows thrice in his face; ſigns him thrice with the ſign of the croſs on the forehead and on the breaſt, and lays his hand upon his head, praying that his "*ancient* error may be put away from him; that his heart may be filled with faith, hope, and charity; and that he may walk in the ways of God's commandments." The prieſt then four times exorciſes the infant, commanding Satan, in the firſt exorciſm, to "tremble, depart, and flee from Chriſt's creature, nor dare to return again, nor dare to lurk concealed within him, or to meet him, or to meditate againſt him, either in the evening or the morning, at midnight or at noon-day." In the laſt exorciſm he blows thrice upon the child's mouth, upon his forehead, and upon his breaſt; ſaying, each time, "Drive away from him every evil and unclean ſpirit that lurks in him, and hath made itſelf a neſt in his heart." The child is now become a catechumen, and, being turned to the weſt, uncovered, without ſhoes, and his hands lifted up, the prieſt repeatedly aſks him if he *renounces* and *has* renounced the Devil and all his works? and receiving from the ſponſor the proper anſwer, he ſays, "Blow and ſpit upon him;" and having blown and ſpit upon the catechumen, he turns him to the eaſt, and holding down his hands, aſks him repeatedly if he be joined to Chriſt, and if he believes in him? The catechumen or his ſponſor replies to each queſtion, that he is, and has been, joined to Chriſt; and as a proof of his

(D) We quote the words of Dr King. Is it poſſible that in the Greek church Latin hymns are uſed, or that Greek hymns have Latin deſignations?

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 baptised 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 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*.

13 The baptismal chrism.

This chrism 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 chrism 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), palm-dew, rose-flowers, black palm-gum, Basil-gum, marjoram, thick and thin oil of nutmegs in very different quantities, oil of cinnamon, oil of cloves, lignum Rhodii, oil of oranges, oil of marjoram, oil of lavendar, 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."

14 The tonsure.

The last ceremony appended to baptism is that of the 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 of

(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° 155. *Encycl,*); 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.

15
The Greeks have three communion-offices.

For the celebration of the Lord's Supper they have three liturgies that are occasionally used, *viz.* that of St Chrysostom, 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 Chrysostom 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 Chrysostom, 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 Chrysostom, 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.

16
Strange ceremony at the offertory.

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 declare 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 Chrysostom 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."

17
The consecration of the elements.

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 is it 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 (G). If the change itself be admitted, the consequence must be the same, whether it be supposed to take place when the

18
Transubstantiation.

(G) 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.

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.

19 The laity communicate in both kinds.

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.

20 Confeſſion in the Greek church.

We have obſerved, that one of the ſeven *myſteries* 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.

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 μνηστρον, 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.

The ſecond ceremony, which is properly the marriage, 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."

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.

22 Regular and ſecular clergy.

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.

23 Five orders of clergy.

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 (H), 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,

24 Form of ordination.

"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 preſbyter,

(H) 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 Abyſſinian, and he is always a foreigner, ſubordinate in his juriſdiction to the patriarch of Alexandria.

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.

25 Solemn conſecration of biſhops.

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 (I) 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.

The laſt ſacrament of the Greek church is that of the holy oil or euchelaion, which is not confined to perſons *perículoſe ægrotantibus, 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.

26 The lavipedium.

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 baſon 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 (K), 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.

27 The privileges of the patriarch of Conſtantinople.

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,

(I) In the Greek church all pariſh prieſts are called *papas* or popes; and the proto-pope is an archpreſbyter.
(K) The firſt goſpel is John xiii. 3—12. The ſecond goſpel is John xiii. 12—18.

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 coſt of China, which were viſited by Lord Macartney in his courſe to Pekin. 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 alluvian 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 Chuſan, 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 Chuſan, 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 ſticks 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 Chuſan, 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 coſt 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 Chuſan iſlands are annexed. From one port in that province twelve veſſels ſail annually for copper to Japan.

According to Brookes, Chuſan 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-

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° 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 Diſſipation*, in optics. See OPTICS, *Encycl.* n° 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. Theſe 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 horfeback; and it was confidered as a point eftablifhed, 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 folemnities.

The wedding carriage of the firft wife of the Emperor Leopold, who was a Spanifh princefs, coft, together with the harnefs, 38,000 florins. The coaches ufed by that Emperor are thus defcribed by Kink: "In the imperial coaches no great magnificence was to be feen; they were covered over with red cloth and black nails. The harnefs was black, and in the whole work there was no gold. The pannels were of glafs, and on this account they were called the *imperial glafs coaches*. On feftivals the harnefs was ornamented with red filk fringes. The imperial coaches were diftinguifhed only by their having leather traces; but the ladies in the imperial fuite were obliged to be contented with carriages, the traces of which were made of ropes." At the magnificent court of Duke Erneft Auguftus of Hanover, there were in the year 1681 fifty gilt coaches with fix horfes each. So early did Hanover begin to furpafs other cities in the number of its carriages. The firft time that ambaffadors appeared in coaches on a public folemnity was at the imperial commiffion held at Erfurth in 1613 refpecting the affair of Juliers.

In the hiftory of France we find many proofs that at Paris, in the 14th, 15th, and even 16th centuries, the French monarchs rode commonly on horfes, the fervants of the court on mules, and the princeffes, together with the principal ladies, fometimes on affes. Perfons of the firft rank often fat behind their equerry, and the horfe was often led by fervants. Carriages, however, of fome kind appear to have been ufed very early in France. An ordinance of Philip the Fair, iffued in 1294 for fuppreffing luxury, and in which the citizens wives are forbid to ufe carriages (*cars*), is ftill preferved. Under Francis I. or rather about 1550, fomewhat later, there were in Paris for the firft time only three coaches.

The oldeft carriages ufed 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 fubjects, he and all his followers were on horfeback; his mother only, who was indifpofed, rode in a carriage. This, however, became afterwards fomewhat unfafhionable, when that monarch's queen, Ann, the daughter of the Emperor Charles IV. fhewed the Englifh ladies how gracefully and conveniently fhe could ride on a fidefaddle. Whirlicotes were laid afide, therefore, except at coronations and other public folemnities. Coaches were firft known in England about the year 1580, and, as Stow fays, were introduced from Germany by Fitzallen, earl of Arundel. In the year 1598, when the Englifh ambaffador came to Scotland, he had a coach with him. Anderfon places the period when coaches began to be in common ufe about the year 1605. The celebrated duke of Buckingham, the unworthy favourite of two kings, was the firft perfon who rode with a coach and fix horfes, in 1619. To ridicule this new pomp, the earl of Northumberland put eight horfes to his carriage.

Refpecting the progrefs of luxury with regard to coaches, the reader will find much curious information in the firft volume of Profeffor Beckmann's *Hiftory of Inventions*. It is perhaps one of the moft entertaining articles in that very learned work. The author, however, with all his labour, has not been able to afcertain the country in which coaches hung on fprings were firft ufed; but he feems inclined to give the credit of the invention to Hungary.

Cobalt. COBALT (fee CHEMISTRY-*Index*, in this Supplement), is a valuable article to potters and dyers. To fit it for their ufe, it is firft roafted and freed from the foreign mineral bodies with which it is united: it is then well calcined, and fold either mixed or unmixed with fine fand under the name of zaffer (*zaffera*); or it is melted with filiceous earth and potafhes to a kind of blue glafs called *fmalt*, which when ground very fine is known in commerce by the name of *powder blue*. All thefe articles, becaufe they are moft durable pigments, and thofe which beft withftand fire, and becaufe one can produce with them every fhade of blue, are employed above all for tinging cryftal and for enamelling; for counterfeiting opaque and tranfparent precious ftones, and for painting and varnifhing real porcelain and earthen and potters ware. This colour is indifpenfably neceffary to the painter when he is defirous of imitating the fine azure colour of many butterflies and other natural objects; and the cheaper kind is employed to give a blueifh tinge to new-wafhed linen, which fo readily changes to a difagreeable yellow, though not without injury to the health as well as to the linen.

Profeffor Beckmann, in his *Hiftory 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, difcovered not long before that period. As it was not known at firft to what ufe it could be applied, it was thrown afide as a ufelefs mineral. The miners had an averfion to it, not only becaufe it gave them much fruitlefs labour, but becaufe it often proved prejudicial to their health by the arfenical particles with which it was combined; and it appears even that the mineralogical name *cobalt* then firft took its rife. At any rate, I have never met with it before the beginning of the 16th century; and Mathefius and Agricola feem to have firft ufed it in their writings. Frifch derives it from the Bohemian word *kow*, which fignifies *metal;* but the conjecture that it was formed from *cobalus*, which was the name of a fpirit that, according to the fuperftitious notions of the times, haunted mines, deftroyed the labours of the miners, and often gave them a great deal of unneceffary trouble, is more probable; and there is reafon to think that the latter is borrowed from the Greek. The miners, perhaps, gave this name to the mineral out of joke, becaufe it thwarted them as much as the fuppofed fpirit, by exciting falfe hopes, and rendering their labour often fruitlefs. It was once cuftomary, therefore, to introduce into the church fervice a prayer that God would preferve miners and their works from *kobolts* and fpirits.

"Refpecting the invention of making an ufeful kind of blue glafs from cobalt, we have no better information than that which Klotzfch has publifhed from the papers of Chriftian Lehmann. The former, author of an hiftorical work refpecting the upper diftrict of the mines in Mifnia, 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 $7\frac{1}{2}$ 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 Leipsic, 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."

Kossler 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 Cornwal.

Coffea.

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 *."

* *Moseley's Treatise on 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 are

are many judicious obfervations, the refult of long experience, refpecting the foil fit for a coffee plantation; the various eftablifhments neceffary; the cultivation of the coffee-tree through the feveral ftages of its growth and duration; and the management and ufe of the negroes and cattle.

With refpect to foil, it is a fact, fays he, beyond contradiction, that low lands, and even the mountains near the champaign country, are lefs proper for the production of coffee, than lands which are high and at a diftance from the fea. The coffee-tree delights in a comparatively cool climate, and in an open and permeable virgin foil; and is hurt by the parching deftructive air of the fea. The foil on the mountains of St Domingo confifts generally of a bed of mould more or lefs deep; but which, for the production of coffee-trees, ought not to be lefs than four or five feet. If the declivity be gentle, the fofteft and moft friable earth is preferable to all others; but in fteep grounds a firm though not clayey foil, mixed with a proportion of gravel or fmall ftones, through which the water may find an eafy way, is the moft defirable. The colour of the ground is of little confequence, though fuch as is fomewhat reddifh is generally to be preferred. With regard to expofure, the north and weft are the moft eligible in low and hot fituations, becaufe thefe expofures are the cooleft; and on the higheft mountains the fouth and eaft are to be chofen, becaufe they are the hotteft. On the whole, neither the higheft nor the loweft fituations are the beft, but thofe which are confiderably above the middle of the mountains.

Whatever be the planter's circumftances in point of fortune, and our author thinks that he ought not to undertake a fettlement without the command of 3000 or 4000 pounds fterling, he ought not to fet out with a great number of negroes. If he cannot command a plentiful fupply of victuals from fome contiguous plantation, fix, or at the moft twelve, male negroes, with one or two women, will be found fufficient to make the firft effay. After building two huts, one for the mafter or overfeer and the other for the flaves, 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 poffible, but the roots are to be left in the ground, becaufe they preferve the foil during the firft period of culture; and in burning this mafs of wood and fhrubs, the only way fometimes of clearing the ground, care muft be taken that the fire be nowhere fo violent as to convert the foil into the confiftence of brick, which it is very apt to do if the foil be clayey. Amid the coffee-trees, after they are planted, may be fown beans, maize, and all kinds of efculent plants, pot herbs, and roots; but particular care muft be taken to remove from thefe plantations all creeping plants, fuch as melons, yams, potatoes, gourds, and more efpecially tobacco, which multiplies to a vaft extent, and exhaufts the ground.

In St Domingo the moft approved method of planting the coffee-tree is in ftraight rows croffing each other at right angles, and the diftance between the plants is regulated by the quality and expofure of the ground. The richer the foil, the expofures being the fame, and the cooler the expofure, the quality of the foil being the fame, the farther muft the trees be planted afunder. If on the north and weft the ground be good, plant ftill farther; but, on the contrary, if to the eaft or fouth it be light (which it generally is), plant ftill nearer. Thus if it be proper on a fouth or eaft expofure to plant at the diftance of fix feet, it will be neceffary to plant at the diftance of feven on a weft or north expofure, if the ground be of the fame quality as in the other fituations.

Though coffee, like all other vegetables, grows from the feed, Dr Laborie advifes, in the forming of large plantations, to make ufe of faplings reared in nurferies; and the fituation fitteft for a nurfery is a plain, or at leaft a ground of gentle afcent, where the mould is crumbly. In forming a nurfery, fome plant the whole cherry; but our author recommends the taking off the fkin, and wafhing the feparated feeds; in which we fufpect that he is miftaken, as his practice is certainly a deviation from nature. The nurfery muft be kept very clear of weeds, and neither corn nor any thing elfe fown in it.

The beft feafon for tranfplanting the faplings is during the genial rains of April and May, when great attention is required, as the treafures of future harvefts are at ftake. Thofe plants are the fitteft for being removed which, in the language of our author, are *crowned*, or have each four little boughs; and, if the feeds were frefh and fown in furrows about an inch from each other, this perfection is generally attained in the courfe of a year. The faplings muft not be pulled up by force, but carefully raifed by means of a flat, fharp, iron fhovel, thruft deep under their roots; and the fooner they are planted, after being taken up, the better.

In planting, the firft thing to be done is to thruft into the ground a dibble, or fharp pointed ftick, 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 diminifhed about four or fix inches; and the plant being fupported with the left hand, in the middle of the hole, while the end of its ftraight root, which our author calls its pivot, touches lightly the new bed, the furrounding mould is with the right hand thrown in, to the height of fix inches. This being lightly preffed down with both hands, more earth is thrown in and preffed in the fame manner, care being taken not to hurt, or bend, or difplace the fapling, which muft be fet fo 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 thefe branches rife above its margin, are filled up by the furrounding earth. The bufinefs is finifhed by finking the fharp-pointed ftick at the upper margin of the hole, where it ferves as a fmall fence to the infant tree. In hot fituations plantain trees are intermingled with the coffee trees for the purpofe of fhade and coolnefs. They are ufually placed in every fourth or fixth row, as the trees are more or lefs diftant, and the expofure more or lefs hot.

To the bufinefs of planting very foon fucceeds that of weeding; for there is hardly any plant to which weeds are fo pernicious as the coffee-tree: they caufe it to grow yellow, fade, wither, and perifh. Where the ground flopes much, efpecially if the foil be foft and friable, the weeds muft be taken up by the hand; for if they be rooted out by the hoe, the foil will be fo loofened that the rains will fweep it away. Some weeds,

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 Forſyth'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.

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.

* *Dr Wright.*

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 the

the aqueous part of its mucilage are deftroyed ; its faline properties are created and difengaged, and its oil is rendered empyreumatic.—From thence arifes the pungent fmell, and exhilarating flavour, not found in its natural ftate.

The roafting of the berry to a proper degree requires great nicety : Du Four juftly remarks, that the virtue and agreeablenefs of the drink depend on it, and that both are often injured in the ordinary method. Bernier fays, when he was at Cairo, where it is fo much ufed, he was affured by the beft judges, that there were only two people in that great city, in the public way, who underftood the preparing it in perfection. If it be under-done, its virtues will not be imparted, and in ufe it will load and opprefs the ftomach :—If it be overdone, it will yield a flat, burnt, and bitter tafte, its virtues will be deftroyed, and in ufe it will heat the body, and act as an aftringent.

Fourteen pounds weight of raw coffee is generally reduced, at the public roafting houfes in London, to eleven pounds by the roafting ; for which the dealer pays feven pence half-penny, at the rate of five fhillings for every hundred weight. In Paris, the fame quantity is reduced to ten pounds and an half. But the roafting ought to be regulated by the age and quality of the coffee, and by nicer rules than the appearance of the fumes, and fuch as are ufually practifed : therefore the reduction muft confequently vary, and no exact ftandard can be afcertained. Befides, by mixing different forts of coffee together, that require different degrees of heat and roafting, coffee has feldom all the advantages it is capable of receiving to make it delicate, grateful, and pleafant. This indeed can be effected no way fo well as by people who have it roafted in their own houfes, to their own tafte, and frefh as they want it for ufe. The clofer it is confined at the time of roafting, and till ufed, the better will its volatile pungency, flavour, and virtues, be preferved.

The mode of preparing this beverage for common ufe differs in different countries, principally as to the additions made to it.—But though that is generally underftood, and that tafte, conftitution, the quality of the coffee, and the quantity intended to be drunk, muft be confulted, 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 underftood, and which admits of no deviation.

The prefervation of the virtues of coffee, particularly when it is of a fine quality, and exempt from ranknefs, as has been faid, depends on carefully confining it after it has been roafted ; and not powdering it until the time of ufing it, that the volatile and ethereal principles, generated by the fire, may not efcape. But all this will fignify nothing, and the beft materials will be ufelefs, unlefs the following important admonition is ftrictly attended to ; which is, that after the liquor is made, it fhould be bright and clear, and entirely exempt from the leaft cloudinefs or foul appearance, from a fufpenfion of any of the particles of the fubftance of the coffee.

There is fcarcely any vegetable infufion or decoction whofe effects differ from its grofs origin more than that of which we are fpeaking. Coffee taken in fubftance caufes oppreffion at the ftomach, heat, naufea, and indigeftion : confequently a continued ufe of a preparation of it, in which any quantity of its fubftance is contained, befides being difgufting to the palate, muft tend to produce the fame indifpofitions. The refiduum of the roafted berry, after its virtues are extracted from it, is little more than an earthy calx, and muft therefore be injurious.

The want of attention to this circumftance has been the caufe of many of the complaints againft coffee, and of the averfion which fome people have to it ; and it is from this confideration that coffee fhould not be prepared with milk inftead of water, nor fhould the milk be added to it on the fire, as is fometimes the cafe, for economical dietetic purpofes, where only a fmall quantity of coffee is ufed, as the tenacity of the milk impedes the precipitation of the grounds, which is neceffary for the purity of the liquor, and therefore neither the milk nor the fugar fhould be added until after it is made with water in the ufual way, and the clarification of it is completed (A).—The milk fhould be hot when added to the liquor of the coffee, which fhould alfo be hot, or both fhould be heated together, in this mode of ufing coffee as an article of fuftenance.

If a knowledge of the principles of coffee, founded on examination and various experiments, added to obfervations made on the extenfive and indifcriminate ufe of it, cannot authorife us to attribute to it any particular quality unfriendly to the human frame ; if the unerring teft of experience has confirmed its utility, in many countries, not exclufively productive of thofe inconveniences, habits, and difeafes, for which its peculiar properties feem moft applicable—let thofe properties be duly confidered ; and let us reflect on the ftate of our atmofphere, the food and modes of life of the inhabitants, and the chronical infirmities which derive their origin from thefe fources, and it will be evident what falutary effects might be expected from the general dietetic ufe of coffee in Great Britain.

COFFER-DAMS, or *Batardeaux*, in bridge-building, are enclofures formed for laying the foundation of piers, and for other works in water, to exclude the furrounding water, and fo prevent it from interrupting the workmen.

COLCHESTER, the chief town in Effex, is defcribed in the Encyclopædia Britannica ; but the defcription is in many refpects erroneous. The following account of it was fent to us by an obliging correfpondent, who is defirous that the place of his nativity may be accurately defcribed in this Supplement.

Colchefter is pleafantly fituated upon an eminence, gradually rifing on the fouth fide 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 *Colneceafter*. That it flourifhed under the Romans, feveral buildings full of their bricks, and innumerable quantities of coin dug

(A) It is not to coffee alone that this reflection is confined ; every article we ufe as a diluter demands the fame attention. Malt liquors, particularly fmall beer, which in this refpect is much neglected, ought always to be carefully fined. The fæculent matter entangled by the mucilage of the malt is hurtful to digeftion, and detrimental to health.

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 Botoph'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 stedfastly 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

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 ſound 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 Benvenut, 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 60 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:

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 ſtedfaſtly 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° 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 Newton, Combustion.

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 Lavoiserian theory as far as it proceeds, divides the bodies which occupy the attention of chemists into, 1. *Combustibles;* 2. *Supporters of combustion;* and, 3. *Incombustiblts.*

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 of

Combustion. 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 incombustibility of products is not owing to their want of affinity for oxygen, but to some other cause.

Though no *mere product* of combustion is capable of *supporting* combustion, this is not occasioned by any want of affinity for combustible bodies; for several of these products are capable of combining with an additional dose of their bases. By this combination, however, they lose their properties as products, and are converted into *combustibles*; whence it follows that the process must differ essentially from that of combustion. Thus sulphuric acid, a *product* of combustion, by combining with an additional dose of sulphur or its oxide, is converted into *sulphurous acid*; a substance which, from many of its properties, Dr Thomson concludes to be *combustible*. Thus also phosphoric acid, a product of combustion, is capable of combining with phosphorated hydrogen, and forming *phosphorous acid*, a combustible body. When this last acid is heated in contact with a supporter, it undergoes combustion; but it is only the additional dose of the combustible which burns, and the whole is converted into phosphoric acid. Hence we see that it is not the whole basis of these compounds that is combustible, but merely the additional dose; and therefore the compounds themselves may be termed *partial combustibles*, to indicate, that *part* only of the base is capable of undergoing combustion. Now, since the products of combustion are capable of combining with oxygen, but never exhibit the phenomena of combustion, except when they are in the state of partial combustibles, combustible bodies must contain some principle, which they lose during combustion, and to which they owe their combustibility; for after they have lost 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 just as supporters do, give it out to combustibles, and convert them into products; but during this process no heat nor light is ever evolved. Water, for instance, gives out its oxygen to iron, and converts it into *black oxide*, a product; and sulphuric acid gives out its oxygen to phosphorus, and converts it into phosphoric acid. Thus we see that the oxygen of products is capable of converting combustibles into products, just as the oxygen of supporters; but during the combination of the last only are heat and light emitted. The oxygen of supporters, then, contains something which the oxygen of products wants.

Whenever the whole of the oxygen is abstracted from products, the combustibility of their base is restored as completely as before combustion; but no substance is capable of abstracting the whole of oxygen, except a *combustible* or a *partial combustible*; and when this is done, the combustible or partial combustible loses its own combustibility by the process, and is converted into a product.

From these facts, which have been all established by Stahl, Lavoisier, and our author, it follows that the products of combustion may be formed without actual combustion: but in these cases a *new combustible* is always evolved. The process is merely an interchange of combustibility; for the combustible is converted into a product only by means of a product. Both the oxygen and the base of the product having undergone combustion, have lost something which is essential to combustion. The process is merely a double decomposition. The product yields its oxygen to the combustible, while, at the same time, the combustible gives out something to the base of the product. The combustibility of that base, then, is restored by the loss of its oxygen, and by the restoration of something which it receives from the other combustible thus converted into a product.

No *supporter* can be produced by combustion, or by any equivalent process. Now as all the supporters, except oxygen gas, consist of oxygen combined with a base, it follows as a consequence, that oxygen may combine with a base, without losing that ingredient, whatever it is, which gives occasion to combustion. The mere act of combination of oxygen with a base, therefore, is by no means the same with combustion.

Several of the supporters and partial supporters are capable of combining with combustibles, without undergoing decomposition, or exhibiting the phenomena of combustion. In this manner the yellow oxide of gold, and the white oxide of silver, combine with ammonia; the red oxide of mercury with oxalic acid; and oxy-muriatic acid with ammonia. Thus also nitre and oxy-muriat of potash may be combined, or at least intimately mixed with several combustible bodies, as in gunpowder, &c. In all these compounds the oxygen of the supporter retains each the ingredients proper to itself, which render them susceptible of combustion; and hence the compound is still combustible. They burn indeed with amazing facility, not only when heated, but when triturated or struck smartly with a hammer; and have received, in consequence, the name of *detonating* or *fulminating* bodies.

Such are the properties of the combustibles, the supporters, and the products; and such the phenomena which they exhibit when made to act upon each other. If we compare together the *supporters* and the *products*, we shall find that they resemble each other in several respects. Both of them contain oxygen as an essential part; both are capable of converting combustibles into products; and of both several combine with combustibles and with additional doses of oxygen. But they differ widely from each other in the phenomena which accompany their action on combustibles. The supporters convert these bodies into products; and at the same time combustion, or the emission of light and heat, takes place; whereas the products convert combustibles into products without any such emission. Now as the ultimate change produced upon combustibles by both these sets of bodies is the same, and as the substance which combines with the combustibles is in both cases the same, namely oxygen, we must conclude that this oxygen in the supporters contains something which the oxygen of the products wants; something which seperates during the passage of the oxygen from the supporter to the combustible, and occasions the combustion, or emission of fire, which accompanies this passage. The oxygen of supporters, then, contains some ingredient

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 phenomena which have been thought inconsistent with that theory.

* *Nicholson's Journal*, vol. ii. Second series.

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 is 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

magnetic powers, which often produces a difference exceeding a point; and I am well convinced that the great errors in fhip-reckonings proceed more frequently from the incorrectnefs of the compafs than from any other caufe.

"Steel cannot be too highly tempered for the needle of a fea-compafs, as the more it is hardened the more permanent is the magnetifm it receives; but, to preferve the magnetifm, and confequently the polarity of the needle, I recommend to have the needle cafed with thin, well-polifhed, foft iron; or elfe to have it armed at the poles with a bit of foft iron. I have found, from many experiments, that the cafed needle preferved its magnetifm in a much more perfect degree than the needle not cafed; and I have fometimes thought that the magnetic power of the cafed needle had inreafed, while the magnetic power of the uncafed and unarmed needle always lofes of its polarity."

This is not an opinion taken up at random, but is the refult of what appears to have been a fair and judicious experiment; for our author placed a cafed needle, an armed needle, and one without either cafe or armour, in a room for three months; each having at that time precifely the fame direction, and nearly the fame degree of force. At the expiration of the three months, he found that the cafed needle and the armed needle had not in the leaft changed their direction; but the other had changed two degrees, and had loft very confiderable of its magnetic power. If there was any change in either of the other needles, it was too inconfiderable to be perceived.

Thefe obfervations feem to be new, and may tend to the improvement of the compafs. But it is not with refpect to the needle only that this inftrument is defective. Mr Bernard Romans of Penfacola well obferves, that, on another account, the heavieft brafs compaffes now in ufe are by no means to be relied on in a hollow or high fea. This is owing to the box hanging in two brafs rings, confining it to only two motions, both vertical and at right angles with each other; by which confinement of the box, upon any fuccuffion, more efpecially fudden ones, the card is always put into too much agitation, and, before it can well recover itfelf, another jerk prevents its pointing to the pole; nor is it an extraordinary thing to fee the card unfhipped by the violence of the fhip's pitching.

All thefe inconveniences are remedied to the full by giving the box a vertical motion at every degree and minute of the circle, and compounding thefe motions with a horizontal one of the box as well as of the card. By this unconfined difpofition of the box, the effects of the jerks on the card are avoided, and it will always very fteadily point to the pole. "Experience (fays our author) has taught me, that the card not only is not in the fmalleft degree affected by the hollow fea, but that, in all the violent fhocks and whirlings the box can receive, the card lies as ftill as if in a room unaffected by the leaft motion.

"Lately a compafs was invented and made in Holland, which has all thefe motions. It is of the fize of the common brafs compaffes; the bottom of the brafs box, inftead of being like a bowl, muft be raifed into a hollow cone, like the bottom of a common glafs bottle; the vertex of the cone muft be raifed fo high as to leave but one inch between the card and the glafs; the box muft be of the ordinary depth, and a quantity of lead muft be poured in the bottom of the box, round the bafe of the cone; this fecures it on the ftile whereon it traverfes.

"This ftile is firmly fixed in the centre of a fquare wooden box, like the common compafs, except that it requires a thicker bottom. The ftile muft be of brafs, about fix inches long, round, and of the thicknefs of one-third of an inch; its head blunt, like the head of a fewing-thimble, but of a good polifh: the ftile muft ftand perpendicular. The inner vertex of the cone muft alfo be well polifhed; the vertical part of the cone ought to be thick enough to allow of a well-polifhed cavity, fufficient to admit a fhort ftile, proceeding from the centre of the card whereon it traverfes. The compafs I faw was fo conftructed; but I fee no reafon why the ftile might not proceed from the centre of the vertex of the cone, and fo be received by the card the common way. The needle muft be a magnetic bar, blunt at each end; the glafs and cover are put on in the common way."

A compafs of this kind was fubmitted to our author's examination by the captain of a floop of war, who affured him, that in a hard gale, which lafted fome days, there was no other compafs of the fmalleft fervice. Mr Romans was fatisfied that the officer did not praife the apparatus more than it deferved; and we feel ourfelves ftrongly inclined to be of the fame opinion.

It muft not be concealed, however, that the ingenious Mr Nicholfon feems to think very differently of all fuch contrivances. In a paper publifhed in the ninth number of his valuable Journal, he labours to prove, that the compafs is very little difturbed by tilting the box on one fide, but very much by fudden horizontal changes of place; that a fcientific provifion againft the latter is therefore the chief requifite in a well made inftrument of this kind; and that no other provifion is requifite or can eafily be obtained, than good workmanfhip according to the common conftruction, and a proper adjuftment of the weight with regard to the centres or axes of fufpenfion. The fame author is of opinion, that it would greatly improve the compafs to make the needle flat and thin, and to fufpend it, not, as is moft commonly done, with its flat fide, but with its edge uppermoft; for it being a well-known fact, that foft fteel lofes its magnetifm fooner than hard, it is obvious, that unlefs both fides of a needle be equally hard (which is almoft impoffible if they be diftant from each other), the magnetic power will, in procefs of time, deviate towards the harder fide.

The Chinefe COMPASS has fome advantages over the European compafs, from which it differs with refpect to the length of the needle, and the manner in which it is fufpended. In the compafs of China, the magnetic needle is feldom above an inch in length, and is lefs than a line in thicknefs. It is poifed with great nicety, and is remarkably fenfible, or, in other words, points fteadily towards the fame portion of the heavens. This fteadinefs is accomplifhed by the following contrivance: "A piece of thin copper is ftrapped round the centre of the needle. This copper is rivetted by its edges to the upper part of a fmall hemifpherical cup, of the fame metal, turned downwards. The cup fo inverted ferves as a focket to receive a fteel pivot rifing from a cavity made into a round piece of light wood or cork, which thus

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 Bussale*, 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;

 and

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 *Higguins* (probably *Higgins*), had ſucceeded in gaining the good-will of theſe ſavages, and thereby rendered 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 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. 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 Leſpinaſſe.

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 Peterſburgh, 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

gration 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 ſplended 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 bookſellers 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 bookſellers, 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

Jacobin

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° 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.

Condorcet.

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 ſully 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 Rocheſoucalt, 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.

* *Jour. de Phyſ.* Nov. 1792.

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 philo-

ſopher

fopher than the tender and courageous anxiety with which fhe watched the couch, and affuaged the fufferings, of the fon of the prefident du Paty, who had been bitten by a mad dog. This union, however, we are told, was fatal to his repofe; it tempted him into the dangerous road of ambition; and the idea of providing for a wife and daughter induced him to feek for offices which once he would have defpifed.

CONFERVA JUGALIS (fee CONFERVA, *Encycl.*) is introduced here merely on account of a curious circumftance refpecting it, which was communicated, not long ago, to the Philomatic Society at Paris. Citizens Charles and Romain Coquebert having collected fome of this *Conferva* in the neighbourhood of Paris, afcertained, by means of an excellent microfcope, conftructed by Nairne and Blunt, that, in this fpecies, there are male and female filaments, which unite by an actual copulation; that certain globules contained in the male filaments pafs into the interior part of the female filaments; and that by this union there are formed in the latter feeds, or, if we may ufe the expreffion, fmall *ova*, which reproduce the fpecies. This is the firft inftance, in the vegetable kingdom, of a reproduction abfolutely analogous to that which we find among animals.—*Philofophical Magazine*, N° 3.

May this fact be depended on? We queftion not, in the flighteft degree, the veracity of the editor of the very refpectable mifcellany from which we have copied it; but we confefs ourfelves inclined to admit the phyfiological difcoveries of citizen philofphers with great hefitation. The fact, if real, is certainly curious, and may lead to important conclufions; and we therefore recommend an inveftigation of its truth to our botanical readers.

CONGELATION. See CHEMISTRY in this Supplement, n° 280—283.

CONTAGION (fee *Encycl.*) is a fubject on which much has been written to very little purpofe. Of all the attempts which have been made to account for it, there is not one that can be thought fatisfactory. This, however, is not perhaps a matter of great importance, if a method could only be difcovered to ftop the progrefs of contagion where it is known to have place. Among the many benefits which may be reaped from the late difcoveries in chemiftry, even this defideratum promifes to be one; and we furely need not add one of the greateft. Dr James Carmichael Smyth, phyfician extraordinary to his Majefty, fuggefted, in the year 1795 or 1796, a procefs for determining the effect of the nitric acid in deftroying contagion; and experiments, according to his directions, were made on board the *Union* and other fhips at Sheernefs.

The Union was an hofpital fhip, and the experiment on board her was conducted by Mr Menzies, late furgeon to his Majefty's floop Difcovery, and by Mr Baffan, furgeon of the Union; and when it is confidered that frefh contagion was daily pouring into the hofpital from the Ruffian veffels, which were at that time lying in the Downs, and which had brought with them a fpecies of fever that might in every fenfe of the word be termed an epidemy, it will be allowed, that the fuccefs which attended it was fuch that it cannot be too generally known.

The wards were extremely crowded, and the fick of every defcription lay in cradles, promifcuoufly arranged, to the number of nearly two hundred; of which about one hundred and fifty were in different ftages of the above malignant fever, which was extremely contagious, as appeared evident from its rapid progrefs and fatal effects among the attendants on the fick and the fhip's company.

The utenfils and materials provided for the procefs were the following: A quantity of fine fand, about two dozen quart earthen pipkins, as many common teacups, fome long flips of glafs to be ufed as fpatulas, a quantity of concentrated vitriolic (fulphuric) acid, and a quantity of pure nitre (nitrat of potafh).

The procefs was conducted in the following manner: *1ft*, All the ports and fcuttles were fhut up; the fand, which had been previoufly heated in iron pots, was then fcooped out into the pipkins by means of an iron ladle; and in this heated fand, in each pipkin, a fmall tea-cup was immerfed, containing about half an ounce of the fulphuric acid, to which, after it had acquired a proper degree of heat, an equal quantity of nitrat of potafh in powder was gradually added, and the mixture ftirred with a glafs fpatula till the vapour arofe from it in confiderable quantity (A). The pipkins were then carried through the wards by the nurfes and convalefcents, who kept walking about with them in their hands, occafionally putting them under the cradles of the fick, and in every corner where any foul air was fupected to lodge. In this manner they continued fumigating, until the whole fpace between decks was fore and aft filled with the vapour, which appeared like a thick haze.

The vapour at firft excited a good deal of coughing among the patients, which gradually ceafed as it became more generally diffufed through the wards; part of this effect, however, was to be attributed to the inattention of thofe who carried the pipkins, in putting them too near the faces of the fick; which caufed them to inhale the ftrong vapour as it immediately iffued from the cups.

The body-clothes and bed-clothes of the fick were as much as poffible expofed to the nitrous vapour during the fumigation; and all the foul linen removed from them was immediately immerfed in a tub of cold water, afterwards carried on deck, rinfed out, and hung up till nearly dry, and then fumigated before it was taken to the wafh-houfe: a precaution extremely neceffary in every cafe of infectious diforder. Due attention was alfo paid to cleanlinefs and ventilation.

It took about three hours to fumigate the fhip. In about an hour after, the vapour having entirely fubfided, the ports and fcuttles were thrown open for the admiffion of frefh air. It could plainly be perceived that

(A) That the fumes of the mineral acids poffeffed the property of ftopping 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 foda (fea falt) by the fulphuric acid, purified the air of the cathedral of Dijon, which had been fo much infected by exhumations that they were obliged to abandon the building. See CHEMISTRY, n 426. in this *Suppl.*

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,

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. Plaining 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, plaining 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 stave 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 stave, it is of little consequence whether it be rounded into the segment of a circle or not, and therefore the cooper very seldom takes that trouble.

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° 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 design

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 orbit, 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 immoveable 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

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 φελλος, 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 Sclavonia, 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 coſmogany, 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 imbelle 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. Thouin*'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 matraſs, 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 court. Correction.

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 rehearsing his warlike atchievements.

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 rasping-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 || Crane.

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.

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 windlaſs.

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 pullies 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*, nº 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:

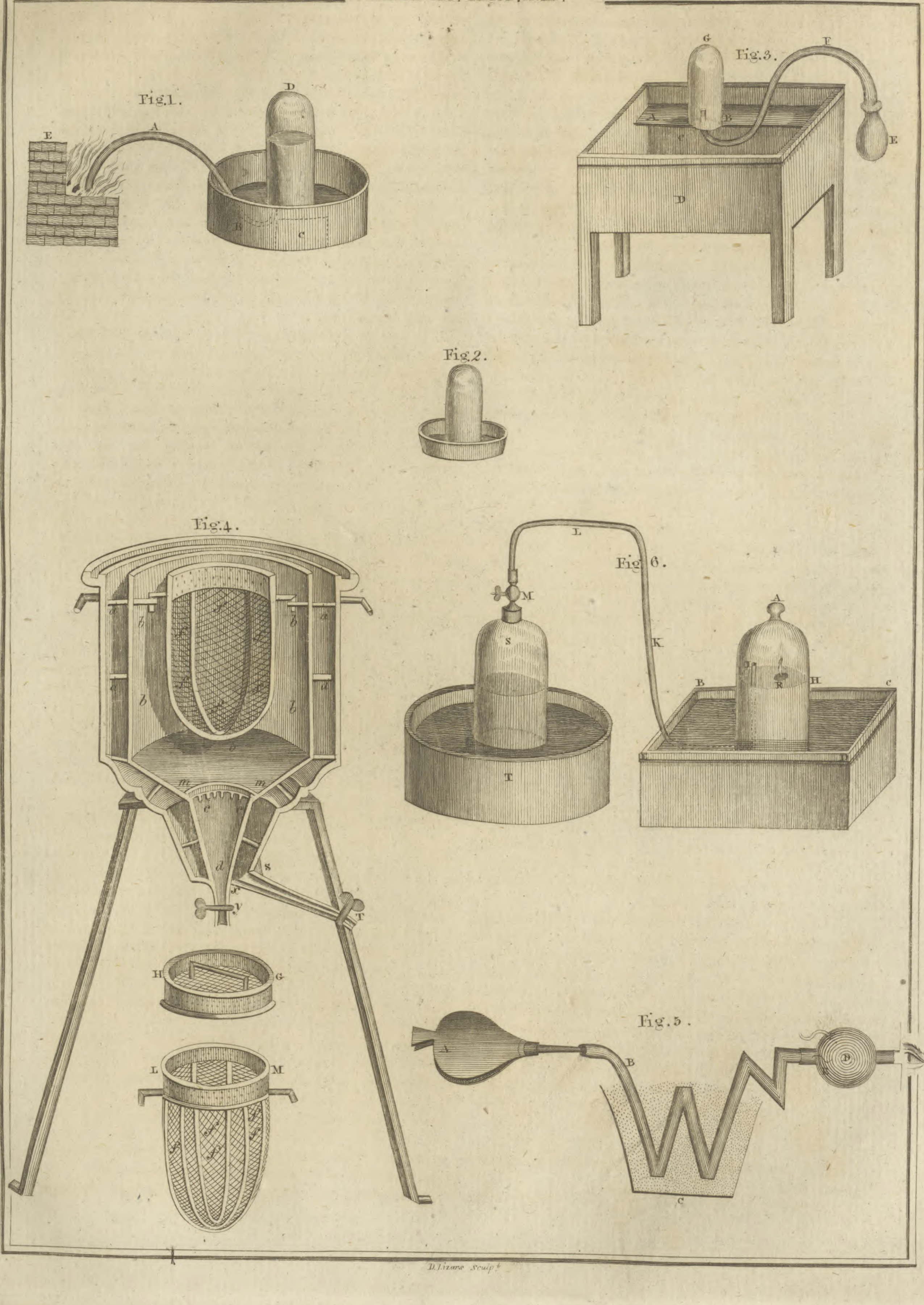
1. It is ſimple, conſiſting merely of a wheel and axle. 2. It has comparatively little friction, as is obvious from the bare inſpection of the figure. 3. It is durable, as is evident from the two properties above mentioned. 4. It is ſafe; for it cannot move but during the pleaſure of the man, and while 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 ſyphon, 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



D. Lizars Sculp.

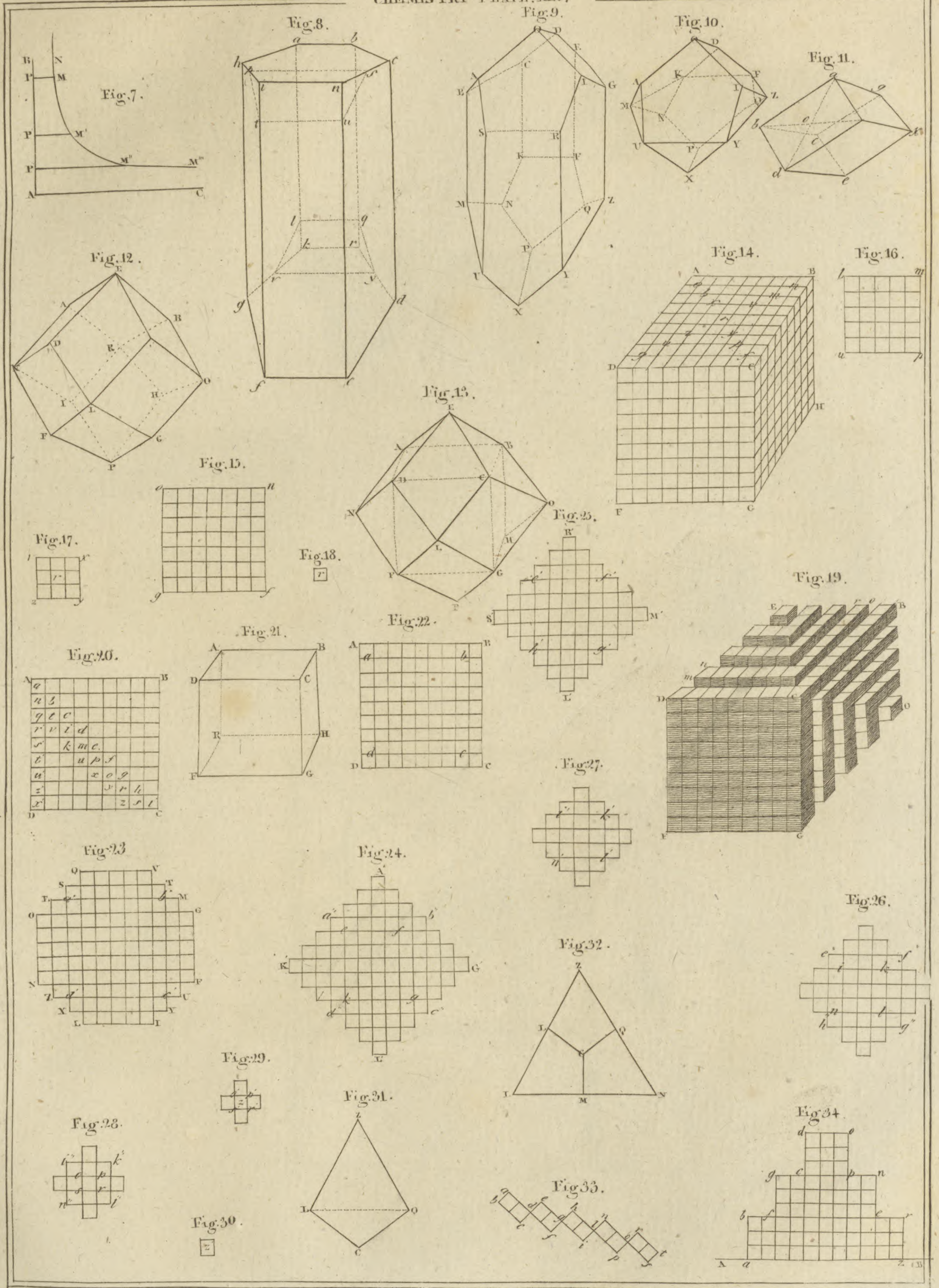


Fig. 7.
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Fig. 33.
Fig. 34.

Fig. 3.

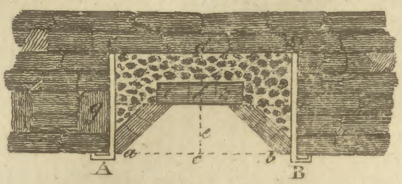


Fig. 5.

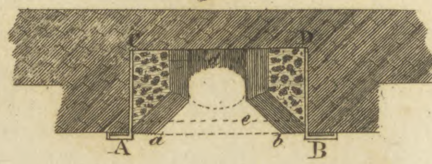


Fig. 8.

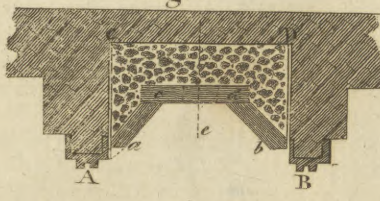


Fig. 4.

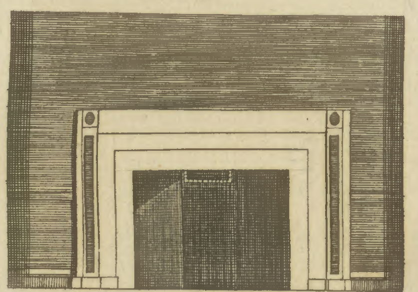


Fig. 7.

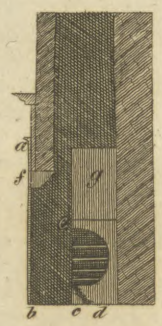
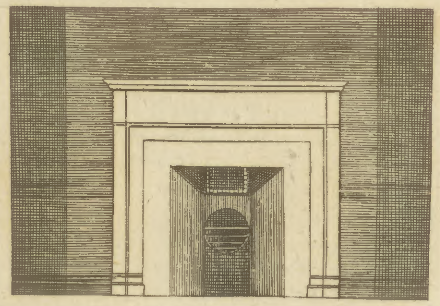


Fig. 6.



Scale 1 2 3 4 5 of Feet

CRANE

Fig. 1.

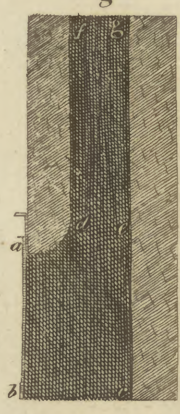


Fig. 1.

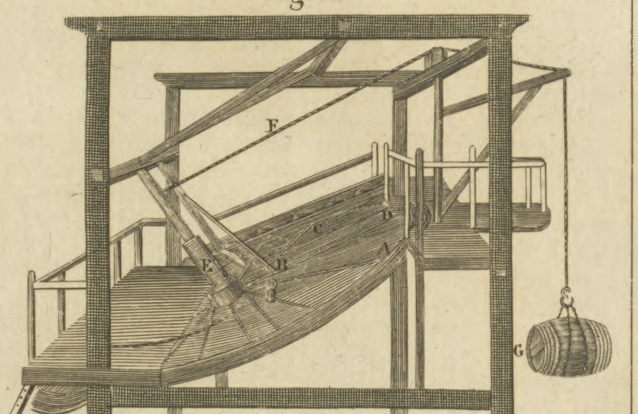
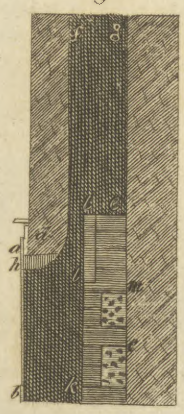


Fig. 2.



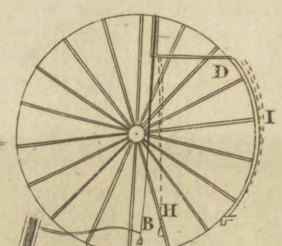


Fig. 2.

Crown, Cruz.

of box or pear-tree, confifting of a fquare ftaff of about three feet long, having each of its faces divided like a line of tangents, and having four crofs pieces of unequal lengths to fit on the ftaff, the halves of thefe being as the radii to the tangent lines on the faces of the ftaff.—The inftrument was ufed in taking the altitudes of the celeftial bodies at fea.

CROWN, in aftronomy, a name given to two conftellations, the fouthern and the northern.

Crown, in geometry, a plane ring included between two parallel or concentric peripheries of unequal circles.

Crown-Poft, is a poft in fome buildings ftanding upright in the middle between two principal rafters; and from which proceed ftruts or braces to the middle of each rafter. It is otherwife called a *king-poft*, or *king's-piece*, or *joggle-piece*.

La CRUZ, an excellent harbour on the north-weft coaft of America, difcovered by the Spaniards in 1779. They were introduced into it by a paffage 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 reafon to queftion the exactnefs of the latitude of this paffage as laid down by the Spaniards; but the editor of Peroufe's voyage juftly concludes, from the furvey made by our celebrated navigator Captain Cook on the coafts adjacent to the entrance of Bucarelli, that this entrance is about 135° 20′ to the weft of Paris, or very nearly 133° weft of Greenwich.

The Spaniards were not long in the harbour of *La Cruz* before they received a vifit from the inhabitants in its neighbourhood. Bartering took place. The Indians gave their peltry, and various trifles, for glafs beads, bits of old iron, &c. By this traffic the Spaniards were enabled to gain a fufficiently exact knowledge of their genius, of their offenfive and defenfive arms, of their manufactures, &c.

Their colour is a clear olive; many among them have, however, a perfectly white fkin: their countenance is well proportioned in all its parts. They are robuft, courageous, arrogant, and warlike.

They clothe themfelves in one or two undreffed fkins (with the fur apparently); thefe are the fkins of otters, of fea-wolves, of benades (a fpecies of deer), of bears, or other animals, which they take in hunting. Thefe dreffes cover them from the neck to the middle of the leg; there are, however, many among them who wear boots of fmooth fkin, refembling Englifh boots, only that thofe of the Indians open before, and are laced tight with a ftring. They wear hats woven from the fine bark of trees, the form of which refembles that of a funnel or a cone. At the wrifts they have bracelets of copper or iron, or for want of thefe metals the fins of whales; and round the neck, necklaces of fmall fragments of bones of fifhes and other animals, and even copper collars of the bignefs of two fingers. They wear in their ears pendants of mother-of-pearl, or flat pieces of copper, on which is emboffed a refin of a topaz colour, and which are accompanied with jet beads. Their hair is long and thick, and they make ufe of a comb to hold it together in a fmall queue from the middle to the extremity; a narrow ribbon of coarfe linen, woven for this purpofe, ferves as a ligament. They wear alfo as a covering a kind of fcarf, woven in a particular manner, fomething more than a yard and a half long, and about half a yard broad, round which hangs a fringe fomething more than half a quarter of a yard deep, of which the thread is regularly twifted.

The women give proofs of their modefty and decency by their drefs. Their phyfiognomy is agreeable, their colour frefh, their cheeks vermilioned, and their hair long; they plait it together in one long trefs. They wear a long robe of a fmooth fkin tied round the loins, like that of a nun; it covers them from the neck as low as the feet; the fleeves reach down to the wrifts. Upon this robe they put divers fkins of otters or other animals to defend themfelves from the inclemency of the weather. Better dreffed, many of them might difpute charms with the moft handfome Spanifh women; but diffatisfied with their natural charms, they have recourfe to art, not to embellifh, but to disfigure themfelves. 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 fhape, of which the fmalleft diameter is almoft an inch; the more a woman is advanced in years, the more this curious ornament is extended: it renders them frightful, the old women efpecially, whofe lip, deprived of its wonted fpring, and dragged by the weight of this extraordinary jewel, neceffarily hangs in a very difagreeable manner. The girls wear only a copper needle, which croffes the lip in the place where the ornament is intended hereafter to be placed.

Thefe Indians in war make ufe of cuiraffes and fhoulder pieces of a manufacture like that of the whalebone ftays among the Europeans. Narrow boards or fcantlings form, in fome fort, the woof of the texture, and threads are the warp: in this manner the whole is very flexible, and leaves a free ufe to the arms for the handling of weapons. They wear round the neck a coarfe and large gorget which covers them as high as below the eyes, and their head is defended by a morion, or fkull-piece, ufually made of the head of fome ferocious animal. From the waift downwards, they wear a kind of apron, of the fame contexture as their cuirafs. Laftly, a fine fkin hangs from their fhoulders down to the knee. With this armour they are invulnerable to the arrows of their enemies; but thus armed, they cannot change pofition with fo much agility as if they were lefs burdened.

Their offenfive arms are arrows; bows, of which the ftrings are woven like the large cords of our beft mufical inftruments; lances, four yards in length, tongued with iron; knives, of the fame metal, longer than European bayonets, a weapon, however, not very common among them; little axes of flint, or of a green ftone, fo hard that they cleave the moft compact wood without injury to their edge.

The pronunciation of their language is extremely difficult; they fpeak from the throat, with a movement of the tongue againft the palate. The little ufe the women make of the inferior lip greatly injures the diftinctivenefs of their language. The Spaniards could neither pronounce nor write the words which they heard.

From the vivacity of fpirit in thefe Indians, and from their attention amply to furnifh the market eftablifhed in the harbour, it may be concluded that they are pretty laborious. They continually brought ftuffs well woven and fhaded by various colours, the fkins of land and fea wolves, of otters, bears, and other fmaller animals;

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

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 converſation 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 copartnery 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 copartnery 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 the

(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.

Cullen.

the ardour of difpofition he poffeffed, it cannot be fuppofed he beheld the fair fex with indifference. Very early in life he took a ftrong attachment to an amiable woman, a Mifs Johnfton, daughter to a clergyman in that neighbourhood, nearly of his own age, who was prevailed on to join with him in the facred bonds of wedlock, at a time when he had nothing elfe to recommend him to her except his perfon and difpofitions; for as to riches and poffeffions he had little of thefe to boaft of. She was beautiful, had great good fenfe, equanimity of temper, an amiable difpofition, and elegance of manners, and brought with her a little money, which, though it would be accounted nothing now, was fomething in thofe days to one in his fituation in life. After giving to him a numerous family, and participating with him the changes of fortune which he experienced, fhe peacefully departed this life in fummer 1786.

In the year 1746, Cullen, who had now taken the degree of doctor in phyfic, was appointed a lecturer in chemiftry in the univerfity of Glafgow: and in the month of October began his lectures in that fcience. His fingular talents for arrangement, his diftinctnefs of enunciation, his vivacity of manner, and his knowledge of the fcience he taught, rendered his lectures interefting to the ftudents to a degree that had been till then unknown at that univerfity. He became, therefore, in fome meafure, adored by the ftudents. The former profeffors were eclipfed by the brilliancy of his reputation; and he had to experience all thofe little rubs that envy and difappointed ambition naturally threw in his way. Regardlefs, however, of thefe fecret fhagreens, he preffed forward with ardour in his literary career; and, fupported by the favour of the public, he confoled himfelf for the contumely he met with from a few individuals. His practice as a phyfician increafed from day to day; and a vacancy having occurred in the year 1751, he was then appointed by the king profeffor of medicine in that univerfity. This new appointment ferved only to call forth his powers, and to bring to light talents that it was not formerly known he poffeffed; fo that his fame continued to increafe.

As, at that period, the patrons of the univerfity of Edinburgh were conftantly on the watch for the moft eminent medical men to fupport the rifing fame of the college, their attention was foon directed towards Cullen; who, on the death of Dr Plumber, profeffor of chemiftry, was, in 1756, unanimonfly invited to accept the vacant chair. This invitation he accepted: and having refigned all his employments in Glafgow, he began his academical career in Edinburgh in the month of October of that year; and there he refided till his death.

If the admiffion of Cullen into the univerfity of Glafgow gave great fpirit to the exertions of the ftudents, this was ftill, if poffible, more ftrongly felt in Edinburgh. Chemiftry, which had been till that time of fmall account in that univerfity, and was attended to by very few of the ftudents, inftantly became a favourite ftudy; and the lectures upon that fcience were more frequented than any others in the univerfity, anatomy alone excepted. The ftudents, in general, fpoke of Cullen with the rapturous ardour that is natural to youth when they are highly pleafed. Thefe eulogiums appeared extravagant to moderate men, and could not fail to prove difgufting to his colleagues. A party was formed among the ftudents for oppofing this new favourite of the public; and thefe ftudents, by mifreprefenting the doctrines of Cullen to others who could not have an opportunity of hearing thefe doctrines themfelves, made even fome of the moft intelligent men in the univerfity think it their duty publicly to oppofe thefe imaginary tenets. The ferment was thus augmented; and it was fome time before the profeffors difcovered the arts by which they had been impofed upon, and univerfal harmony reftored.

During this time of public ferment, Cullen went fteadily forward, without taking any part himfelf in thefe difputes. He never gave ear to any tales refpecting his colleagues, nor took any notice of the doctrines they taught: That fome of their unguarded ftrictures might at times come to his knowledge, is not impoffible; but if they did, they feemed to make no impreffion on his mind.

Thefe attempts of a party of ftudents to lower the character of Cullen on his firft outfet in the univerfity of Edinburgh having proved fruitlefs, his fame as a profeffor, and his reputation as a phyfician, became more and more refpected every day. Nor could it well be otherwife: Cullen's profeffional knowledge was always great, and his manner of lecturing fingularly clear and intelligible, lively and entertaining; and to his patients, his conduct in general as a phyfician was fo pleafing, his addrefs fo affable and engaging, and his manner fo open, fo kind, and fo little regulated by pecuniary confiderations, that it was impoffible for thofe who had occafion to call once for his medical affiftance, ever to be fatisfied on any future occafion without it. He became the friend and companion of every family he vifited; and his future acquaintance could not be difpenfed with.

But if Dr Cullen in his public capacity deferved to be *admired*, in his private capacity by his ftudents he deferved to be *adored*. His conduct to them was fo attentive, and the intereft he took in the private concerns of all thofe ftudents who applied to him for advice, was fo cordial and fo warm, that it was impoffible for any one who had a heart fufceptible of generous emotions, not to be enraptured with a conduct fo uncommon and fo kind. Among ingenuous youth, gratitude eafily degenerates into rapture—into refpect nearly allied to adoration. Thofe who advert to this natural conftruction of the human mind, will be at no lofs to account for that popularity that Cullen enjoyed—a popularity, that thofe who attempt to weigh every occurrence by the cool ftandard of *reafon* alone, will be inclined to think exceffive. It is fortunate, however, that the bulk of mankind will ever be influenced in their judgment not lefs by feelings and affections than by the cold and phlegmatic dictates of *reafon*. The adoration which generous conduct excites, is the reward which nature hath appropriated exclufively to difinterefted beneficence. This was the fecret charm that Cullen ever carried about with him, which fafcinated fuch numbers of thofe who had intimate accefs to him. This was the power which his envious opponents never could have an opportunity of feeling.

The general conduct of Cullen to his ftudents was thus. With all fuch as he obferved to be attentive and diligent, he formed an early acquaintance, by inviting them by twos, by threes, or by fours at a time, to fup with him, converfing with them on thefe occafions with the

the moft engaging eafe, and freely entering with them on the fubject of their ftudies, their amufements, their difficulties, their hopes, and future profpects. In this way he ufually invited the whole of his numerous clafs, till he made himfelf acquainted with their abilities, their private character, and their objects of purfuit. Thofe among them whom he found moft affiduous, beft difpofed, or the moft friendlefs, he invited the moft frequently, till an intimacy was gradually formed, which proved highly beneficial to them. Their doubts, with regard to their objects of ftudy, he liftened to with attention, and folved with the moft obliging condefcenfion. His library, which confifted of an excellent affortment of the beft books, efpecially on medical fubjects, was at all times open for their accommodation; and his advice, in every cafe of difficulty to them, they always had it in their power moft readily to obtain. They feemed to be his family; and few perfons of diftinguifhed merit have left the univerfity of Edinburgh in his time, with whom he did not keep up a correfpondence till they were fairly eftablifhed in bufinefs. By thefe means he came to have a moft accurate knowledge of the ftate of every country, with refpect to practitioners in the medical line; the only ufe he made of which knowledge was, to direct ftudents in their choice of places, where they might have an opportunity of engaging in bufinefs with a reafonable profpect of fuccefs. Many, very many, able men has he thus put into a good line of bufinefs where they never could have thought of it themfelves; and they are now reaping the fruits of this beneficent forefight on his part.

Nor was it in this way only that he befriended the ftudents at the univerfity of Edinburgh. Poffeffing a benevolence of mind that made him ever think firft of the wants of others, and recollecting the difficulties that he himfelf had had to ftruggle with in his younger days, he was at all times fingularly attentive to their pecuniary concerns. From his general acquaintance among the ftudents, and the friendly habits he was on with many of them, he found no difficulty in difcovering thofe among them who were rather in hampered circumftances, without being obliged to hurt their delicacy in any degree. To fuch perfons, when their habits of ftudy admitted of it, he was peculiarly attentive. They were more frequently invited to his houfe than others; they were treated with more than ufual kindnefs and familiarity; they were conducted to his library, and encouraged by the moft delicate addrefs to borrow from it freely whatever books he thought they had occafion for: and as perfons in thefe circumftances were ufually more fhy in this refpect than others, books were fometimes preffed upon them as a fort of conftraint, by the Doctor infifting to have their opinion of fuch or fuch paffages they had not read, and defiring them to carry the book home for that purpofe. He, in fhort, behaved to them rather as if he courted their company, and ftood in need of their acquaintance than they of his. He thus raifed them in the opinion of their acquaintance to a much higher degree of eftimation than they could otherwife have obtained; which, to people whofe minds were depreffed by penury, and whofe fenfe of honour was fharpened by the confcioufnefs of an inferiority of a certain kind, was fingularly engaging. Thus they were infpired with a fecret fenfe of dignity, which elevated their minds, and excited an uncommon ardour of purfuit, inftead of that melancholy inactivity which is fo natural in fuch circumftances, and which too often leads to defpair. Nor was he lefs delicate in the manner of fupplying their wants, than attentive to difcover them. He often found out fome polite excufe for refufing to take payment for a firft courfe, and never was at a lofs for one to an after courfe. Before they could have an opportunity of applying for a ticket, he would fometimes lead the converfation to fome fubject that occurred in the courfe of his lectures; and as his lectures were never put in writing by himfelf, he would fometimes beg the favour to fee their notes, if he knew they had been taken with attention, under a pretext of affifting his memory. Sometimes he would exprefs a wifh to have their opinion of a particular part of his courfe, and prefented them with a ticket for that purpofe; and fometimes he refufed to take payment, under the pretext that they had not received his full courfe the preceding year, fome part of it having been neceffarily omitted for want of time, which he meant to include in this courfe. By fuch delicate addrefs, in which he greatly excelled, he took care to forerun their wants. Thus he not only gave them the benefit of his own lectures, but by refufing to take their money, he alfo enabled them to attend thofe of others that were neceffary to complete their courfe of ftudies. Thefe were particular devices he adopted to individuals to whom economy was neceffary; but it was a general rule with him, never to take money from any ftudent for more than two courfes of the fame fet of lectures, permitting him to attend thefe lectures as many years longer as he pleafed *gratis*.

He introduced another general rule into the univerfity, that was dictated by the fame principle of difinterefted beneficence, that ought not to be here paffed over in filence. Before he came to Edinburgh, it was the cuftom of medical profeffors to accept of fees for their medical affiftance, when wanted, even from medical ftudents themfelves, who were perhaps attending the profeffor's own lectures at the time. But Cullen never would take fees as a phyfician from any ftudent at the univerfity, though he attended them, when called in as a phyfician, with the fame affiduity and care as if they had been perfons of the firft rank, who paid him moft liberally. This gradually induced others to adopt a fimilar practice; fo that it is now become a general rule for medical profeffors to decline taking any fees when their affiftance is neceffary to a ftudent. For this ufeful reform, with many others, the ftudents of the univerfity of Edinburgh are folely indebted to the liberality of Dr Cullen.

The firft lectures which Cullen delivered in Edinburgh were on chemiftry; and for many years he alfo gave clinical lectures on the cafes which occurred in the Royal Infirmary. In the month of February 1763, Dr Alfton died, after having begun his ufual courfe of lectures on the materia medica; and the magiftrates of Edinburgh, as patrons of that profefforfhip in the univerfity, appointed Dr Cullen to that chair, requefting that he would finifh the courfe of lectures that had been begun for that feafon. This he agreed to do; and though he was under a neceffity of going on with the courfe in a few days after he was nominated, he did not once think of reading the lectures of his predeceffor, but refolved to deliver a new courfe entirely his own

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Cullen.

The popularity of Cullen at this time may be gueffed at by the increafe of new ftudents who came to attend his courfe in addition to the eight or ten who had entered to Dr Alfton. The new ftudents exceeded 100. An imperfect copy of thefe lectures, thus fabricated in hafte, having been publifhed, the Doctor thought it neceffary 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 thofe ftriking beauties that characterifed his literary exertions in the prime of life.

Some years afterwards, on the death of Dr White, the magiftrates once more appointed Dr Cullen to give lectures on the theory of phyfic in his ftead. And it was on that occafion Dr Cullen thought it expedient to refign the chemical chair in favour of Dr Black, his former pupil, whofe talents in that department of fcience were then well known, and who filled the chair till his death with great fatisfaction to the public*. Soon after, on the death of Dr Rutherford, who for many years had given lectures with applaufe on the practice of phyfic, Dr John Gregory (whofe name can never be mentioned by any one who had the pleafure of his acquaintance without the warmeft tribute of a grateful refpect) having become a candidate for this place along with Dr Cullen, a fort of compromife took place between them; by which they agreed each to give lectures alternately on the theory and on the practice of phyfic during their joint lives, the longeft furvivor being allowed to hold either of the claffes he fhould incline. In confequence of this agreement, Dr Cullen delivered the *firft* courfe of lectures on the practice of phyfic in winter 1766, and Dr Gregory fucceeded him in that branch the following year. Never perhaps did a literary arrangement take place that could have proved more beneficial to the ftudents than this. Both thefe men poffeffed great talents, though of a kind extremely diffimilar. Both of them had certain failings or defects, which the other was aware of, and counteracted. Each of them knew and refpected the talents of the other. They co-operated, therefore, in the happieft manner, to enlarge the underftanding, and to forward the purfuits of their pupils. Unfortunately this arrangement was foon deftroyed by the unexpected death of Dr Gregory, who was cut off in the flower of life by a fudden and unforefeen event. After this time, Cullen continued to give lectures on the practice of phyfic till a few months before his death, which happened on the 5th of February 1790, in the 77th year of his age.

* See *Black*, Suppl.

In drawing the character of Dr Cullen, Dr Anderfon, to whom we are indebted for this fketch, obferves, that in fcientific purfuits men may be arranged into two grand claffes, which, though greatly different from each other in their extremes, yet approximate at times fo near as to be blended indifcriminately together; thofe who poffefs a talent for detail, and thofe who are endowed with the faculty of arrangement. The firft may be faid to view objects individually as through a microfcope. The field of vifion is confined; but the objects included within that field, which muft ufually be confidered fingly and apart from all others, are feen with a wondrous degree of accuracy and diftinctnefs. The other takes a fweeping view of the univerfe at large, confiders every object he perceives not individually, but as a part of one harmonious whole: His mind is therefore not fo much employed in examining the feparate parts of this individual object, as in tracing its relations, connections, and dependencies, on thofe around it.—Such was the turn of Cullen's mind. The talent for arrangement was that which peculiarly diftinguifhed him from the ordinary clafs of mortals; and this talent he poffeffed perhaps in a more diftinguifhed degree than any other perfon of the age in which he lived. Many perfons exceeded him in the minute knowledge of particular departments, who, knowing this, naturally looked upon him as their inferior; but poffeffing not at the fame time that glorious faculty, which, "with an eye wide roaming, glances from the earth to heaven," or the charms which this talent can infufe into congenial minds, felt difguft at the pre-eminence he obtained, and aftonifhment at the means by which he obtained it. An Ariftotle and a Bacon have had their talents in like manner appretiated; and many are the perfons who can neither be exalted to fublime ideas with Homer, nor ravifhed with the natural touches of a Shakefpeare. Such things are wifely ordered, that every department in the univerfe may be properly filled by thofe who have talents exactly fuited to the tafk affigned them by heaven.

Had Cullen, however, poffeffed the talents for arrangement alone, fmall would have been his title to that high degree of applaufe he has attained. Without a knowledge of *facts*, a talent for arrangement produces nothing but chimeras; without materials to work upon, the ftructures which an over-heated imagination may rear up are merely "the bafelefs fabric of a vifion." No man was more fenfible of the juftnefs of this remark than Dr Cullen, and few were at greater pains to avoid it. His whole life, indeed, was employed, almoft without interruption, in collecting facts. Whether he was reading, or walking, or converfing, thefe were continually falling into his way. With the keen perception of an eagle, he marked them at the firft glance; and without ftopping at the time to examine them, they were ftored up in his memory, to be drawn forth as occafion required, to be confronted with other facts that had been obtained after the fame manner, and to have their truth afcertained, or their falfity proved, by the evidence which fhould appear when carefully examined at the impartial bar of juftice. Without a memory retentive in a fingular degree, this could not have been done; but fo very extraordinary was Dr Cullen's memory, that till towards the very decline of life, there was fcarcely a fact that had ever occurred to him which he could not readily recollect, with all its concomitant circumftances, whenever he had occafion to refer to it. It was this faculty which fo much abridged his labour in ftudy, and enabled him fo happily to avail himfelf of the labour of others in all his literary fpeculations. He often reaped more by the converfation of an hour than another man would have done in whole weeks of laborious ftudy.

In his prelections, Dr Cullen never attempted to read. His lectures were delivered *viva voce*, without having been previoufly put into writing, or thrown into any particular arrangement. The vigour of his mind was fuch, that nothing more was neceffary than a few fhort notes before him, merely to prevent him from varying from the general order he had been accuftomed to obferve. This gave to his difcourfes an eafe, a vivacity,

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vacity, a variety, and a force, that are rarely to be met with in academical difcourfes. His lectures, by confequence, upon the fame fubject were never exactly the fame. Their general tenor indeed was not much varied; but the particular illuftrations were always new, well fuited to the circumftances that attracted the general attention of the day, and were delivered in the particular way that accorded with the caft of mind the prelector found himfelf in at the time. To thefe circumftances muft be afcribed that energetic artlefs elocution, which rendered his lectures fo generally captivating to his hearers. Even thofe who could not follow him in thofe extenfive views his penetrating mind glanced at, or who were not able to underftand thofe apt allufions to collateral objects which he could only rapidly point at as he went along, could not help being warmed in fome meafure by the vivacity of his manner. But to thofe who could follow him in his rapid career, the ideas he fuggefted were fo numerous, the views he laid open were fo extenfive, and the objects to be attained were fo important—that every active faculty of the mind was roufed; and fuch an ardour of enthufiafm was excited in the profecution of ftudy, as appeared to be perfectly inexplicable to thofe who were merely unconcerned fpectators. In confequence of this unfhackled freedom in the compofition and delivery of his lectures, every circumftance was in the niceft unifon with the tone of voice and expreffion of countenance, which the particular caft of mind he was in at the time infpired. Was he joyous, all the figures introduced for illuftration were fitted to excite hilarity and good humour: was he grave, the objects brought under view were of a nature more folemn and grand: and was he peevifh, there was a peculiarity of manner in thought, in word, and in action, which produced a moft ftriking and interefting effect. The languor of a nervelefs uniformity was never experienced, nor did an abortive attempt to excite emotions that the fpeaker himfelf could not at the time feel, ever produce thofe difcordant ideas which prove difgufting and unpleafing.

It would feem as if Dr Cullen had confidered the proper bufinefs of a preceptor to be that of putting his pupils into a proper train of ftudy, fo as to enable them to profecute thofe ftudies at a future period, and to carry them on much farther than the fhort time allowed for academical prelections would admit. He did not, therefore, fo much ftrive to make thofe who attended his lectures deeply verfed in the particular details of objects, as to give them a general view of the whole fubject; to fhew what had been already attained refpecting it; to point out what remained yet to be difcovered; and to put them into a train of ftudy that fhould enable them at a future period, to remove thofe difficulties that had hitherto obftructed our progrefs; and thus to advance of themfelves to farther and farther degrees of perfection. If thefe were his views, nothing could be more happily adapted to them than the mode he invariably purfued. He firft drew, with the ftriking touches of a mafter, a rapid and general outline of the fubject, by which the whole figure was feen at once to ftart boldly from the canvas, diftinct in all its parts, and unmixed with any other object. He then began anew to retrace the picture, to touch up the leffer parts, and to finifh the whole in as perfect a manner as the ftate of our knowledge at the time would permit. Where materials were wanting, the picture there continued to remain imperfect. The wants were thus rendered obvious; and the means of fupplying thefe were pointed out with the moft careful difcrimination. The ftudent, whenever he looked back to the fubject, perceived the defects; and his hopes being awakened, he felt an irrefiftible impulfe to explore that hitherto untrodden path which had been pointed out to him, and fill up the chafm which ftill remained. Thus were the active faculties of the mind moft powerfully excited; and inftead of labouring himfelf to fupply deficiencies that far exceeded the power of any one man to accomplifh, he fet thoufands at work to fulfil the tafk, and put them into a train of going on with it, when he himfelf fhould be gone to that country "from whofe dread bourne no traveller returns."

It was to thefe talents, and to this mode of applying them, that Dr Cullen owed his celebrity as a profeffor; and it was in this manner that he has perhaps done more towards the advancement of fcience than any other man of his time, though many individuals might perhaps be found who were more deeply verfed in the particular departments he taught than he himfelf was. Chemiftry, which was before his time a moft difgufting purfuit, was by him rendered a ftudy fo pleafing, fo eafy, and fo attractive, that it is now profecuted 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 moft diftant idea that they owe any obligations to him; and the fame may be faid of the other branches of fcience which he taught.

According to a man who knew him well, there are three things which eminently diftinguifhed Cullen as a profeffor. "The energy of his mind, by which he viewed every fubject with ardour, and combined it immediately with the whole of his knowledge.

"The fcientific arrangement which he gave to his fubject, by which there was a *lucidus ordo* to the dulleft fcholar. He was the firft perfon in this country who made chemiftry ceafe to be a chaos.

"A wonderful art of interefting the ftudents in every thing which he taught, and of raifing an emulative enthufiafm among them."

We are well aware that this character will by many be deemed an extravagant panegyric; but having no opportunity of judging for ourfelves, we would rather adopt from others an extravagant panegyric than an unmerited cenfure. Dr Anderfon himfelf admits that Cullen's character was far from perfect; and, in the opinion of moft other men with whom we have converfed on the fubject, and who were at the fame time qualified to form an eftimate of his mental powers, his imagination was not balanced by his judgment. Hence the common remark in the univerfity of Edinburgh, that Dr Cullen was more fuccefsful in demolifhing the theories of others than in giving ftability to thofe which were reared by himfelf.

Dr Cullen's external appearance, though ftriking and not unpleafing, was not elegant. His countenance was expreffive, and his eye in particular remarkably lively, and at times wonderfully penetrating. In his perfon he was tall and thin, ftooping very much about the fhoulders. When he walked, he had a contemplative look, and

and did not feem much to regard the objects around him.

CURFEU Bell (fee Curfew, *Encycl.*), called in the law Latin of the middle ages *ignitegium* or *pyritegium*, and in French, *cuvre-feu*—was a fignal for all perfons to extinguifh their fires at a certain hour. In thofe ages people made fires in their houfes 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 fhut by a cover of wood or of earth. This practice ftill prevails among the cottagers in fome parts of Scotland, and we doubt not of other countries. In the dark ages, when all ranks of people were turbulent, a law was almoft everywhere eftablifhed, that the fire fhould be extinguifhed at a certain time in the evening; that the cover fhould be put over the fire-place; and that all the family fhould retire to reft, or at leaft keep within doors The time when this ought to be done was fignified 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 abolifhed by Henry I. in 1100.

The ringing of the curfeu-bell gave rife to the prayer-bell, as it is called, which is ftill retained in fome Proteftant countries. Pope John XXIII. with a view to avert certain apprehended misfortunes, which rendered his life uncomfortable, gave orders, that every perfon, on hearing the *ignitegium*, fhould repeat the *Ave Maria* three times. When the appearance of a comet, and a dread of the Turks, afterwards alarmed all Chriftendom, Pope Calixtus III. increafed thefe periodical times of prayer, by ordering the prayer-bell to be rung alfo at noon. *Beckmann's Hiftory of Inventions.*

CURVE of Equable Approach. It was firft propofed by Leibnitz, namely, to find a curve, down which a body defcending by the force of gravity fhall make equal approaches to the horizon in equal portions of time. It has been found by Bernoulli and others, that the curve is the fecond cubical parabola, placed with its vertex uppermoft, and which the defcending body muft enter with a certain determinate velocity. Varignon rendered the queftion general for any law of gravity, by which a body may approach towards a given point by equal fpaces in equal times. And Maupertuis alfo refolved the problem in the cafe of a body defcending in a medium which refifts as the fquare of the velocity.

CUSSO, or Banksia Abyssinica, is a beautiful and ufeful tree, indigenous to the high country of Abyffinia. At leaft Mr Bruce, who has given of it the only defcription which we have feen, fays that he never faw it in any other part of Afia or Africa. It feldom grows above 20 feet high, very rarely ftraight, generally crooked or inclined. Its leaf, which is of a deep unvarnifhed green, having the fore part covered with foft hair or down, is about $2\frac{1}{4}$ inches long, divided by a ftrong rib into two unequal divifions, of which the upper is broader and larger than the lower. It is more indented than even the nettle leaf, which it in fome meafure refembles, only the leaf of the *Cuffo* is narrower and longer.

Thofe 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 fingle leaf or *ftipula* at the point. The end of this ftalk is broad and ftrong, like that of a palm branch. It is not folid 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 ftalk, bare for about an inch and a quarter, from which proceed crooked branches with fingle flowers attached to their ends; the ftalk that carries thefe proceeds out of every crook or geniculation. The whole clufter of flowers has very much the fhape of a clufter of grapes; the ftalks which fupport it refemble the ftalks of the grape; and a very few fmall leaves are fcattered through the clufter of flowers.

"The calyx or flower cup is of a *greenifh* colour, tinged with purple; when fully blown it is altogether of a deep *red* or purple; the corolla is *white*, and confifts of five petals; in the midft is a fhort piftil with a round head, furrounded by eight ftamina, of the fame form, loaded with yellow farina. The cup confifts of five petals, which much refemble another flower; they are rounded at the top, and nearly of an equal breadth every way. The feed is very fmall, fmaller than even the femen fantonicum; and being likewife very bitter it is ufed in Abyffinia as a vermifuge. From its fmallnefs, however, and its being very eafily fhed, no great quantity of it is ever gathered, and therefore the flower is often fubftituted in its ftead. The Abyffinians, fays our author, of both fexes, and at all ages, are troubled with the fort of worm called afcarides, of which every individual evacuates a large quantity once a-month. The method of promoting thefe evacuations is by infufing a handful of dry cuffo flowers in about two Englifh quarts of bouza, or the beer they make of teff (fee Teff, *Encycl.*), and after it has been fteeped all night, the next morning it is fit for ufe.

"The bark of the tree is fmooth, of a yellowifh white, interfperfed with brown ftreaks, which pafs through the whole body of the tree. It is not firm or hard, but rather ftringy and reedy. On the upper part, before the firft branch of leaves fet out, are rings round the trunk, of fmall filaments of the confiftence of horfe hair: thefe are generally fourteen or fixteen in number, and are a very remarkable characteriftic belonging to the tree."

From this defcription, which, it muft be confeffed, is not remarkable for perfpicuity, and from an infpection of the figure which Mr Bruce has given of the cuffo, we are inclined to rank it with the palms, as a new genus, neareft 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, funk and running along the middle of the great dry ditch, to hold water; ferving both to keep off the enemy and prevent him from mining.

CYCLE of Indiction, is a feries of 15 years, returning conftantly around like the other cycles, and commenced from the third year before Chrift; whence it happens that if 3 be added to any given year of Chrift, and the fun be divided by 15, what remains is the year of the indiction.

CYCLOID (fee *Encycl.*) is a curve, which is thus generated: Suppofe a wheel or circle to roll along a ftraight line till it has completed juft one revolution; a nail or point in that part of the circumference of the circle, which at the beginning of the motion touches the ftraight line, will, at the end of the revolution, have defcribed on a vertical plane a cycloid.

DAGELET,

D.

Dagelet, Dairy.

DAGELET, the name given by *La Peroufe*, the celebrated though unfortunate navigator, to an ifland on the coaft of Corea (fee COREA, *Encycl.*), which he difcovered in the year 1787. It is little more than three leagues in circumference; and our author almoft made its circuit at the diftance of a mile without finding bottom. This fmall fpot is very fteep, but covered with the fineft trees from the fea-fhore to the fummit. A rampart of bare rock, like a wall, encircles the whole outline of it, with the exception of feven little fandy creeks, where it is poffible to land. In thefe creeks the Frenchmen faw upon the ftocks fome boats of a conftruction altogether Chinefe; but the fight of their fhips frightened the workmen, who fled from their dock-yard into the wood, which was not more than fifty paces diftant. As a few huts were feen, but neither villages nor cultivation, La Peroufe concluded that the ifland is without inhabitants, and that the men whom he faw at work were Corean carpenters, who during the fummer months go with provifion to Dagelet for the purpofe of building boats, which they fell upon the continent. He places the north-eaft point of this ifland in Lat. 37°. 25′. and E. Long. 129°. 2′. from Paris.

DAIRY is a word which fignifies fometimes the art of making various kinds of food from milk; fometimes the place where milk is manufactured; and fometimes the management of a milk-farm. On the *dairy*, in the firft and fecond of thefe fenfes, enough has been faid 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 eftablifhed, the undertaker may fometimes think it his intereft to obtain the greateft poffible quantity of produce; fometimes it may be more beneficial for him to have it of the fineft quality; and at other times it may be neceffary to have both thefe objects in view, the one or the other in a greater or lefs proportion: it is therefore of importance that he fhould know how he may accomplifh the one or the other of thefe purpofes in the eafieft and moft direct manner.

To be able to convert his milk to the higheft poffible profit in every cafe, he ought to be fully acquainted with every circumftance refpecting the manufacture both of butter and of cheefe; as it may in fome cafes happen, that a certain portion of that milk may be more advantageoufly converted into butter than into cheefe, while another portion of it would return more profit if made into cheefe.

The firft thing to be adverted to, in an undertaking of this nature, is to choofe cows of a proper fort. Among this clafs of animals, it is found, by experience,

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that fome kinds give milk of a much thicker confiftence and richer quality than others; nor is this richnefs of quality neceffarily connected with the fmallnefs of the quantity yielded by cows of nearly an equal fize; it therefore behoves the owner of a dairy to be peculiarly attentive to this circumftance. 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 itfelf: this is a circumftance that will be fhewn hereafter to be of more importance than is generally imagined. The fmall cows of the Alderney breed afford the richeft milk hitherto known; but individual cows in every country may be found, by a careful felection, that afford much thicker milk than others; thefe therefore ought to be fearched for with care, and their breed reared with attention, as being peculiarly valuable.

Few perfons 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 refpective qualities, particular attention muft be paid to the time that has elapfed fince their calving; for the milk of the fame cow is always thinner foon after calving than it is afterwards; as it gradually becomes thicker, though generally lefs in quantity, in proportion to the time fince the cow has calved. The colour of the milk, foon after calving, is richer than it is afterwards; but this, efpecially for the firft 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 muft at all times have plenty of food. Grafs is the beft food yet known for this purpofe, and that kind of grafs which fprings up fpontaneoufly on rich dry foils is the beft of all. If the temperature of the climate be fuch as to permit the cows to graze at eafe throughout the day, they fhould be fuffered to range on fuch paftures at freedom; but if the cows are fo much incommoded by the heat as to be prevented from eating through the day, they ought in that cafe to be taken into cool fhades for protection; where, after allowing them a proper time to ruminate, they fhould be fupplied with abundance of green food, frefh-cut for the purpofe, and given to them by hand frequently, in fmall quantities, frefh and frefh, fo as to induce them to eat it with pleafure. When the heat of the day is over, and they can remain abroad with eafe, they may be again turned into the pafture, where they fhould be allowed to range with freedom all night, during the mild weather of fummer.

Cows, if abundantly fed, fhould be milked three times a-day, during the whole of the fummer feafon (A); in the

(A) If cows be milked only twice in the day (24 hours), while they have abundance of fucculent food, they will yield a much fmaller quantity of milk, in the fame time, than if they be milked three times. Some attentive obfervers think a cow, in thefe circumftances, will give nearly as much milk at each time, if milked three times, as if fhe were milked only twice. This fact, however, has not, that we know of, been afcertained by experiment. There can be no doubt but they give more, how much more is not afcertained; nor, whether it would be advantageous, in any cafe, 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 houſewifes, 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:

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.

Aphoriſm 2.

"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."

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.

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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.

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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, would

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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 ſourneſs. 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 portion 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.

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 Repertory 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 sattin: 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 livers, 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 from

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 Masuah 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 *Gungunnah*, 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 abondoned 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 myhrrh, 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. 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 well rounded periods, and every thing which had 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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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 minutiæ 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, accompanied 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 extenuation 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 justiciary; 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 *e* at the end.

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ted; but it cannot be denied, that the same fastidiousness, and the same microscopic attention to minutiæ, 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 their 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.

"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 Omniscient 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 judgement 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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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."

A specimen of a book entitled "Ane Compendious Booke of Godly and Spiritual Sangs, 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 Arniston, 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 Malcolmi*; 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 abducat? 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 Ferguſſon, 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, Eq. 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 Menteeth, 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 Hallidon, 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 Tarracona 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, Cœcilius 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 Porteous 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 ſeu 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

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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.

Dalrymple, Darcy.

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

(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.

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 becomes 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 ·222, &c. and is marked thus $\cdot\dot{2}$.

A *pure multiple* circulate is that in which ſeveral figures are continually repeated; as ·232323, &c. marked $\cdot\dot{2}\dot{3}$; and ·524524, &c. marked $\cdot\dot{5}2\dot{4}$.

A *mixed ſingle* circulate is that which conſiſts of a terminate part, and a ſingle repeating figure; as 4·222, &c. or $4\cdot\dot{2}$. And

A *mixed multiple* circulate is that which contains a terminate part with ſeveral repeating figures; as $45\cdot\dot{5}2\dot{4}$.

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 $.\dot{2}$ is $= \frac{2}{9}$; and $\cdot\dot{2}\dot{3}$ is $= \frac{23}{99}$; and $\cdot\dot{5}2\dot{4}$ 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 acceptation, 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

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 theodelite, 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 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

med and fitted, that at 3 having only its lower part quickfilvered, the upper part being left tranfparent to view the object; the fpeculum at A being fixed obliquely, fo that a line A 1, drawn perpendicular to its furface, may bifect the angle BAC in equal parts; that at C being perpendicular to the line C 2; thofe at E and 3 being perpendicular to the index E 3, and that at E being furnifhed with a fight; the arch DC to be divided from D in the manner of Hadley's quadrant; the movement of the index to be meafured as before by a micrometer; and as the length of the line AE would tend to the perfection of the inftrument, it may be conftructed to fold up in the middle, on the line C 2, into lefs compafs when not in ufe. The inftrument may be adjufted for ufe by holding up a ftaff at a diftance, as before propofed, whofe length is exactly equal to the line AE.

To make an obfervation by this inftrument, it being previoufly properly adjufted, the eye is to be applied at the fight in the fpeculum E, and the face turned towards the object; when the object being received on the fpeculum 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 fpeculum at 3 exactly coincides with the real object in the tranfparent part of the glafs, the divifions on the arch D 3, fubdivided by the micrometer, will determine the angle DE 3 = the angle AOE; from which the diftance O may be determined as before.

DENOMINATOR of a Ratio is the quotient arifing from the divifion of the antecedent by the confequent. Thus, 6 is the denominator of the ratio 30 to 5, becaufe 30 divided by 5 gives 6. It is otherwife called the *exponent* of the ratio.

DEPRESSION of a Star, or *of the Sun*, is its diftance below the horizon; and is meafured by an arc of a vertical circle, intercepted between the horizon and the place of the ftar.

Depression of the Vifible Horizon, or *Dip of the Horizon*, denotes its finking or dipping below the true horizontal plane, by the obferver's eye being raifed above the furface of the fea; in confequence of which, the obferved altitude of an odject is by fo much too great.

DEROOBUST, in Bengal, Entire; as an entire diftrict, oppofed to Kismut, which fee.

DESAULT (Peter Jofeph), furgeon in chief to the Hofpital 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 fituation of life which is removed from want, and yet does not difpenfe with labour; he himfelf was the youngeft child of a numerous family.

At Lure, under the direction of a private inftructor, he was taught the firft rudiments of the Latin tongue; his parents afterwards confided him to the care of the Jefuits, then almoft exclufively entrufted with the education of youth in the public fchools. This celebrated fociety, prompt in difcovering, as expert at developing, and adroit in appropriating talents, foon diftinguifhed the young ftudent from the crowd; and he, in his turn, was not difpleafed with the life he led in one of their feminaries.

On the completion of his ftudies, his father, who had deftined him for the church, intimated a wifh that he fhould apply himfelf to theology; but his genius had taken a different direction, and he was averfe to the profeffion of an ecclefiaftic: in fhort, young Default declared that he was determined to betake himfelf to the ftudy of the healing art; and, after a long and ineffectual refiftance on the part of his family, he was fent to Béfort, in order to ferve an *apprenticefhip*, as it was then termed, in the military hofpital of that place. He accordingly fpent three years there; during which he acquired fome knowledge of anatomy, attended to the dreffing of the patients, and endeavoured to fupply, by his own obfervations, what was wanting in his inftruction.

Iu the midft of thefe profeffional labours, his mind frequently rambled towards another fcience but little connected with furgery: this was mathematics, the elements of which he had acquired among the Jefuits. His progrefs in this favourite ftudy was rapid; but he fell into one of the many errors fo common among the phyficians of that day; this confifted in a falfe application of the rules of geometry to the laws of the animal economy.

He not only perufed with avidity the treatife of Borelli *De Motu Animalium*, but actually tranflated the whole of it, and even added a commentary, ftill more abundant in calculation than that of the celebrated profeffor of Naples.

His fuccefs in a branch of phyfiology fo much cultivated at that time, attracted the attention of one of his fuperiors, a zealous partizan of the doctrine of the mechanicians, who wifhed to attach him to his perfon; but his defire of fame required a more extenfive theatre, and his love of ftudy made him folicitous of better means of inftruction. Paris prefented both thefe advantages; and he accordingly repaired thither in 1764, at the age of nineteen, in fearch of them.

Surgery at that period flourifhed in the capital under the aufpices of a Lafaye, a Morand, an Andouillet, and a Louis. The fight of fuch great mafters excited the genius of thofe who afpired to emulate them: young Default deemed himfelf worthy of equalling men whom other ftudents were content with only admiring. Animated by this fentiment, he entirely refigned himfelf to his ardour; anatomy became the fpecial object of his labours, and his diffections were not confined to the human body, for he inveftigated, by means of his knife, a prodigious number of animals of all kinds: at firft, from a difficulty of procuring human fubjects, 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 neceffary to compare it with whatever has a refemblance to it in other bodies.

He accordingly fpent the greater part of the day in the amphitheatres. The hours ftolen from his favourite labours were employed in attending the hofpitals; he was the firft at the bed of the patient where an operation was to be performed, and was fure to be prefent at the dreffings, on purpofe to examine the refult. The infirmities of mankind, fterile in refpect to the vulgar, ferved him as the beft treatife for curing them; and the great furgeons of all nations have formed their mode of practice by contemplating the fame book.

But

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 Haukensiani 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 whice 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 chirurgical instruments; such as those employed in the cases

(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.

cases of polypus in the womb and nostrils *(la pince à gaîne 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 gorgeret*) 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 Chirurgerie*, 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 sandes élastiques*), on their first appearance, fixed the attention of all professional men ; but none knew better than Default how to appretiate 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 faviour. 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'arr t* 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 Malesherbes 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'Ecolede 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 Chopart 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

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, nº 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 forementioned 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, nº 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, 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, hepatized 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 $1\frac{1}{2}$ 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 JACOBINS 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.

Diderot. Our author was more usefully employed in 1746, when, together with Messrs *Eidous* and *Toussant*, 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 *Encyclopædia* 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.

A

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 Baſtile. 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 aukward 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 ſolicitudes, 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 Inter-

Diderot. Interpretation of Nature, 1754, 12mo. This interpreter is very obfcure. 5. The Code of Nature, 1755, 12mo; which is certainly not the code of Chriftianity. 6. The Sixth Senfe, 1752, 12mo. 7. Of Public Education; one of that fwarm of publications produced by the appearance of Emelius, and the abolition of the Jefuits. Though all the ideas of this author could not be adopted, yet fome of them are very judicious, and would be highly ufeful in the execution. 8. Panegyric on Richardfon. Full of nerve and animation. 9. Life of Seneca. This is the laft work which he acknowledged; and it is one of thofe by Diderot that is perufed with moft pleafure, even in rectifying the judgments he paffes on Seneca and other celebrated men. The Abbé Barruel fays, that he was the anthor of *Syfteme de la Nature*, which is ufually given to Robinet; and it is certain, that if he was not the author, he furnifhed hints, and revifed the whole. Yet the junto of atheifts were themfelves afhamed of the firft edition of that work; and after all Diderot's care to improve it, the fubfequent editions are, notwithftanding his boafted knowledge of the laws of nature, contemptible in the eyes of a real mechanical philofopher.

When a new edition of the *Encyclopedie* was refolved on, Diderot, the editor of the former edition, thus addreffes the bookfellers who had undertaken to republifh it. "The imperfections (fays he) of this work originated in a great variety of caufes. We had not time to be very fcrupulous in the choice of our coadjutors. Among fome excellent perfons, there were others weak, indifferent, and altogether bad. Hence that motley appearance of the work, where we fee the rude attempt of the fchool-boy by the fide of a piece from the hand of a mafter; a piece of nonfenfe next neighbour to a fublime performance. Some working for no pay, foon loft their firft fervour; others, badly recompenfed, ferved us accordingly. The *Encyclopedie* was a gulf into which all kinds of fcribblers promifcuoufly threw their contributions; their pieces ill conceived, and worfe digefted, good, bad, contemptible, true, falfe, uncertain, and always incoherent and unequal; the reference that belonged to the very parts affigned to a perfon, never filled up by him. A refutation is often found where we fhould naturally expect a proof. There was no exact correfpondence between the text and the plates. To remedy this defect, recourfe was had to long explications. But how many unintelligible machines, for want of letters to denote the plates!" To this confeffion Diderot added particular details on various parts; fuch as proved that there were in the *Encyclopedie* fubjects to be not only retouched, but to be compofed afrefh: and this was what a new company of literati and artifts fet themfelves to work upon in the *Encyclopedie Methodique*.

This immenfe work is not yet completed; and therefore we cannot fpeak of it as a whole; but it is furely not lefs verbofe than the former edition, nor do the aims of its editors appear to be purer. That it contains much valuable information in chemiftry, and indeed in every department of phyfical fcience, no candid man will controvert: but its articles on abftract philofophy are prolix and obfcure; and it betrays the fame impiety, the fame eager defire to corrupt the principles of the rifing generation, and the fame contempt for every thing which can make mankind happy here or hereafter, with the former edition.

Notwithftanding his numerous publications, Diderot was never rich. Soon after the publication of the laft volumes of the *Encyclopedie*, upon which he had been employed for upwards of twenty years, his circumftances were fo ftraitened, that an expedient was to be devifed for their improvement. He had long correfponded with the late Emprefs of Ruffia, whom he perfuaded to confider him as the greateft, or *one* of the greateft economifts of France. In the courfe of the correfpondence he had mentioned his own library as one of the moft valuable in Europe; and when Catharine wanted to purchafe it and make him librarian, he faid that his conftitution could not fupport the cold climate of St Peterfburgh. She offered to let him keep it during his lifetime in Paris; and the library was fold for an immenfe price. When her ambaffador wanted to fee it, after a year or two's payments, and the vifitation could be no longer put off, Diderot was obliged to run in a hurry through all the bookfellers fhops in Germany to fill his empty fhelves with old volumes. He had the good fortune to fave appearances; but the trick took air, becaufe he had been niggardly in his attention to the ambaffador's fecretary. This, however, did not hinder him from vifiting his imperial pupil, to whom he told a poor ftory, in hopes of getting his daughter married with parade, and patronifed by her majefty; but it was feen through, and he was difappointed.

In the year 1784 Diderot's health began vifibly to decline; and one of his domeftics, perceiving that his death was at no great diftance, acquainted him with his apprehenfions, and addreffed him on the importance of preparing for another world. He heard the man with attention, thanked him kindly, acknowledged that his fituation required ferioufnefs, and promifed to weigh well what he had faid. Some time after this converfation he defired that a prieft might be brought; and the fame domeftic introduced to him M. de Farfac, Curé de St Sulpice. Diderot faw this ecclefiaftic feveral times, and was preparing to make a public recantation of his errors. Condorcet and the other adepts now crowded about him, perfuaded him that he was cheated, that his cafe was not fo dangerous as it was faid to be, and that he only wanted the country air to reftore him to health. For fome time he refifted their attempts to bring him back to atheifm, but was at laft prevailed upon to try the effect of the country air. His departure was kept fecret, and he was concealed in the country till the 2d of July, when he died. His dead body was fecretly brought back to Paris, and a report was fpread and believed that he died fuddenly on rifing from the table, without remorfe, and with his atheifm unfhaken.

To draw a formal character of this wretch is furely fuperfluous. His friends extol his franknefs, his difintereftednefs, and his integrity; but except his grofs avowal of atheifm, which may in France be called franknefs, this character is belied by every tranfaction 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 houfe, found him explaining to this daughter a chapter of the gofpel. When he expreffed fome furprife at this conduct, Diderot faid: "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 "il 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, B^2, B^3, B^4, &c. the first order of differences; C, C^2, C^3, &c. the second order of differences; D, D^2, &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, B^2, B^3, &c. the second differences C, C^2, C^3, &c. the third differences D, D^2, D^3, &c. and so on.

Then if T stand for the first term of the nth 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			
b		C		
	B^2		D	
		C^2		E
c	B^3		D^2	
		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 nth 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 nth 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 nth term of the series A, b, c, d, &c. will be $= A + \frac{n-1}{1} d' + \frac{n-1}{1} \times \frac{n-2}{2} d'' + \frac{n-1}{1} \times \frac{n-2}{2} \times \frac{n-3}{3} d''' + \frac{n-1}{1} \times \frac{n-2}{2} \times \frac{n-3}{3} \times \frac{n-4}{4} d^{v\prime} +$ &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'', $d^{n\prime}$, &c. the first of the several orders of differences; then

The sum of n terms of the series is $= na + n \times \frac{n-1}{2} d' + n \times \frac{n-1}{2} \times \frac{n-2}{3} d'' + n \times \frac{n-1}{2} \times \frac{n-2}{3}$

×

$\times \frac{n-3}{4} d''' + n \times \frac{n-1}{2} \times \frac{n-2}{3} \times \frac{n-3}{4} \times \frac{n-4}{5} d'''' +$, &c.

For in the ſeries of quantities,

	o ,	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 $\overline{n+1}$th term of the ſeries, $o, a, a+b, a+b+c, a+b+c+d$, &c. or the $\bar{n}$th term of the ſeries, $a, a+b, a+b+c, a+b+c+d$, &c. is $= o + na + n \times \frac{n-1}{2} d' + n \times \frac{n-1}{2} \times \frac{n-2}{3} d'' +$ &c. But the nth 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 Arithmeticis, 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 alhidade 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 befal 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 Whiſton, 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. Tranſ. vol. 23.

2. A Treatiſe on Spherical Catoptrics, publiſhed in the Philoſ. Tranſ. for 1705; from whence it was copied and reprinted in the Acta Eruditorem 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.

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 Taiſnier, 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, Witſen 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, 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.

DRACŒNA Draco (see Dracoena, *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

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

thereof, and found the bog to be what has been defcribed under the firft clafs. He therefore determined to attempt the cure in the manner before prefcribed for that clafs, namely, to cut through the whole of the ftratum (in this inftance, of quick-fand), through which he found the water pafs. This he effected as follows: The fummer being dry, and favourable for the purpofe, and having previoufly made his main open drain, he began his main clofe drain the firft week in June 1791, three feet wide, on the declivity near the edge of the great bog. In the firft operation he dug through the peat, the hard fand, and gravel, and one fpade's graft (about nine inches deep, and feven inches wide) into the quick-fand the whole length of this drain, which was 73 perches, of eight yards to the perch, in length. The drain thus dug ran copioufly, not lefs than 60 gallons per minute. In this ftate 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 fpade's graft, which had been made into the quick-fand perfectly dry. He then dug out thefe three inches of dry fand, to nearly the whole width of the drain, three feet; and at the fame time dug out, as before, another fpade's graft from the top of the quick-fand, as near the middle of the drain as poffible. This was left to run a few days, as before, and had the fame effect, namely, three or four inches more of the top of the quick-fand became dry and hard. The fame operation was repeated again and again with the fame effect, till the purpofe of getting through this quick-fand was completed, fo far at leaft as the level of the main open drain would permit. The ftream of water continued increafing during the whole operation; the bog below the drain was quite dry, and the land above perfectly fo. The drain which was firft made, and continued running for fome time during the progrefs of the main clofe drain, became gradually dry; and has not, fince that drain was finifhed, difcharged one fingle drop of water. Great care was neceffary, in making the main clofe drain, to keep the ftream of water in the middle of it, otherwife the current would have undermined the fides, as it fometimes had done, and caufed them to fall in. For this reafon it was neceffary, when the dry fand was taken from the top of the quick-fand, immediately to take out a fpade's graft from the middle thereof, in order to divert the current from the fides.

The main clofe drain thus made was three feet wide at top, about nine feet deep on the average, and, bevelling a little from the top, it was about one foot ten inches wide at the bottom. The ftone and other materials were put into this drain in the following manner:

Where the drain went through the quick-fand into the ftratum of clay below it, as in moft places it did, the bottom, and in fome inftances the fides, wanted no particular fecurity (A); but where it did not go quite through the quick-fand, which the level of his main open drain in fome 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 their edges on each fide of the bottom of the drain, forming two fides of a trough of peat; then fide ftones about eight inches high, and a ftone 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 fpace, of more than fix inches fquare, for the water to pafs. 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 leaft 14 fhillings per acre of yearly rent. He likewife hollow-drained nine acres by the method prefcribed for the third clafs of wet land. Thefe drains were made a few yards below that part of each field where the dry and wet land feparate, about 22 inches deep, with fides and a coverer of ftone, and ling on the top of it, to keep the earth from running in. The length of thefe drains was 880 yards, and the expence of labour and materials three halfpence per yard. The drains, in wet weather, difcharge a large quantity of water; and will, he has no doubt, anfwer the intended purpofe. Thus far relates to land in his own occupation.

Nine acres of the land in the earl of Aylesford's occupation was almoft an entire pulp. This bog was of the fecond clafs, namely, water paffing through a quick-fand, and confined by a ftratum of clay below, and another ftratum of clay above it. The water thus confined, being preffed by its fountain, and forced up thro' the weakeft parts of the clay, had formed a bog of irregular thicknefs on the furface, in fome places fix feet deep, in others not more than two. As there is a confiderable fall in this land from eaft to weft, he thought it expedient to put two drains into it; and this appears to him to have been neceffary, from a confideration that both thefe drains continue to run in the fame proportions as when firft opened. The manner in which thefe drains were executed was, by digging through the different upper ftrata, 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-fand, at the diftance of about fix yards in a progreffive manner.

The water rifing rapidly through thefe holes into the clofe drains, has effected a complete cure of this land, every part of which will now bear a horfe to gallop upon it. Thefe drains difcharge 3660 gallons an hour; which is much lefs than they did at firft, as muft be the cafe in all bogs. This land will be worth twenty fhillings per acre. The draining coft twenty-five pounds; and the length of the under-ground drains is eight hundred and fourteen yards.

Mr Wedge had juft finifhed (January 1792) draining another piece of land, about forty-three acres. As this was intended to anfwer two purpofes, one, to drain the land, the other, to give an additional fupply of water to a mill-pool, and as a circumftance arofe in the execution of the work which frequently happens in draining land, namely, a fudden alteration in the pofition

(A) He will probably find in time that he was under the fame miftake with Mr Bayley, and we hope that with Mr Bayley's candour he will acknowledge it.

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 quick-sand which conveyed the water now became of twice its former thickness; and the clay, which had hitherto been above that quick sand, for some distance disappeared. From the quick-sand 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 quick-sand, 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 quick-sand; 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 hogsheads in a day; which is after the rate of 1,379,700 hogsheads 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 unsound. 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 viscous 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 viscous 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 Whithering 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 drossera with ants and other diminutive insects, he commonly found them perish in a shorter time than fifteen minutes. His experiments were made on the drossera 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 atricle, 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

 in

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. 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.

DYNAMICS.

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 change of that condition 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 concourſe 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.

4 Mechanical relation, what. When we look around us, we cannot but obſerve that the motions of bodies have, in moſt caſes, if not 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.

5
But the analogy is not in the force, but in the effect.

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, nº 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.

6
Directions for the ſafe employment of this analogy.

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.

7
Action implies change; and mere motion is not action.

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

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 *Preſſion, impulſion.*

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 preſſion.

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.

Gravity, attractions, and repulſions, are conſidered as preſſions.

Several writers, however, ſubdivide this great claſs into preſſions 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 impulſion.**

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 ſaltneſs, 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.

Communication of motion, not a good expreſſion.

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 ſtriken. 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.

11
And ſaid to be infinitely greater than preſſion.

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*.

Arguments indiſtinct and inconcluſive.

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.

No difference between preſſion and impulſion.

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.

12
Is impulſion the ſole cauſe of motion?

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

a

a refult of certain motions; and it is the bufinefs of a philofopher to inquire and difcover what motions produce the preffures that we obferve.

They then proceed to account for thofe preffing powers, or folicitations to motion, which we obferve in the acceleration of falling bodies, the attractions of magnetifm 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 diftance. To fay that a magnet cannot act on a piece of remote iron, is to fay that it can act *where* it is not; which is as abfurd as to fay, that it can act *when* it is not. *Nihil movetur*, fays Euler, *nifi a contiguo et moto.*

How does it produce preffure? The bulk of thefe philofophers are not very anxious about the way in which thefe motions are produced, nor do they fall upon fuch ingenious methods of producing preffure as the one already mentioned, which was adduced by Euler. The piece of iron, fay they, is put in motion when brought into the neighbourhood of a magnet, becaufe there is a ftream of fluid iffuing from one pole of the magnet, which circles round the magnet, and enters at the other pole: This ftream impels the iron, and arranges it in certain determined pofitions, juft as a ftream of water would arrange the flote grafs. In the fame manner, there is a ftream of fluid continually moving towards the centre of the earth, which impels all bodies in lines perpendicular to the furface; and fo on with regard to other like phenomena. Thefe motions are thus reduced to very fimple cafes by impulfion.

Incompatible with the rules of philofophifing. It is unneceffary to refute this doctrine at prefent; it is enough that it is contrary to all the dictates of common fenfe. To *fuppofe* an agent that we do not fee, and for whofe exiftence we have not the fmalleft argument; with equal propriety we might fuppofe miniftering fpirits, or any thing that we pleafe.

13 Others maintain that preffure is the fole moving force. Other philofophers are fo diffatisfied with this notion of the production of preffure, that they, on the other hand, affirm that preffure is the only moving force in nature; not according to the popular notion of preffure, by the mutual contact of folid bodies, but that kind of preffure which has been called *folicitation;* fuch as the power of gravity. They affirm, that there is no fuch thing as contact on inftantaneous communication of motion by real collifion. They fay (and they prove it by very convincing facts (fee Optics, n° 63—68. *Encycl.*), that the particles of folid bodies exert very ftrong repulfions to a fmall diftance; and therefore, when they are brought by motion fufficiently 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 diminifhed. And they then fhew, by a fcrupulous confideration of the ftate of the bodies while the one is advancing and the other retiring, in what manner the two bodies attain a common velocity, fo that the quantity of motion before collifion remains unchanged, the one body gaining as much as the other lofes. They alfo fhew cafes of fuch mutual action between bodies, where it is evident that they have never come into contact; and yet the refult has been precifely fimilar to thofe cafes where the motion appeared to be changed in an inftant. Therefore they conclude, that there is no fuch thing as inftantaneous *communication*, or transfufion of motion, by contact in collifion or impulfe. The reafon why previous motion of the impelling body is neceffary, is not that it may have a *vis infita 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 itfelf, whether in motion or at reft.—According to thefe philofophers, therefore, all moving forces are of that kind which has been named *folicitation;* fuch as gravity. We fhall know it afterwards by the more familiar and defcriptive name of Accelerating or Retarding force.

14 *Action, Refiftance, Reaction.* The exertions of mechanical forces are differently termed, according to the reference that we make to the refult. If, in boxing or wreftling, I ftrike, or endeavour to throw my antagonift, I am faid to act; but if I only parry his blows, or prevent him from throwing me, I am faid to resist. This diftinction is applied to the exertions of mechanical powers. When one body A changes the motion of another B, we may confider the change in the motion of B either as the indication and meafure of A's power of producing motion, or as the indication and meafure of A's refiftance to the being brought to reft, or having its motion any how changed. The diftinction is not in the thing itfelf, but only in the reference that we are difpofed, by other confiderations, to make of its effect. They may be diftinguifhed in the following manner: If a change of motion follow when one of the powers ceafes to be exerted, that power is conceived as having refifted. The whole language on this fubject is metaphorical. Refiftance, effort, endeavour, &c. are words which cannot be employed in mechanical difcuffions without figure, becaufe they all exprefs notions which relate to fentient beings; and the unguarded indulgence of this figurative language has fo much affected the imagination of philofophers, that many have almoft animated all matter. Perhaps the word Reaction, introduced (we think) by Newton, is the beft term for expreffing that mutual force which is perceived in all the operations of nature that we have inveftigated with fuccefs. As the magnet attracts iron, and in fo doing is faid to *act* on it; fo the iron attracts the magnet, and may be faid to *react* on it.

15 We need not fuppofe action at a diftance. *Tendency.* With refpect to the difficulty that has been objected to the opinion of thofe who maintain that all the mechanical phenomena are produced by the agency of attracting or repelling forces; namely, that this fuppofes the bodies to act on each other at a diftance, however fmall thofe diftances may be, which is thought to be abfurd, we may obferve, that we may afcribe the mutual approaches or receffes to tendencies to or from each other. What we call *the attraction of the magnet* may be confidered as a tendency of the iron to the magnet, fomewhat fimilar to the gravitation of a ftone toward the earth. We furely (at leaft 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 abfurdity: and we do not know any thing about the nature or effence of matter which renders this tendency to the magnet impoffible. That we do not fee intuitively any reafon why the iron fhould approach the magnet, muft be granted; but this is not enough to entitle us to fay, that fuch a thing is impoffible or inconfiftent with the nature of matter. It appears, therefore, to be very hafty and unwarrantable, to fuppofe the impulfe of an invifible fluid, of which we know nothing, and of the exiftence of which we have no proof. Nay, 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.

16 *Attraction, Repulsion,* are figurative terms

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.

17 Forces are conceived as measurable quantities.

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.

How measured.

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. By their effects.
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

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 demonſtrative 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 *diſciplinæ accuratæ*.

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 oppoſition to other forces.

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 mutual, 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 rectilineal 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 continued motion indicate continued action?

Theſe philoſophers therefore aſſert, that the continual action of the moving cauſe is *eſſentially* neceſſary 23 Whimſical notion element for minds.

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 φυσις and ὑπερψυχη of Ariſtole, which they call an ELEMENTAL MIND, which is the cauſe of *all* its motions and changes. An overweaning 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." Κινειται, *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; "*dvigatſu*," in Sclavonic; 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 gives 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 characteriſed 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.

24 Action not neceſſary for the continuance of motion.

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. 25.

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. 26.

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 27 Inactivity of matter denied by Leibnitz. *Monads*, what.

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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.

28 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, rectilineal, 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 rectilineal 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 unbent 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.

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 ſidewiſe 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 rectilineal motion; yet this ſeems abſolutely neceſſary before we can ſay that we have eſtabliſhed this propoſition experimentally. 30 Common experience inſufficient.

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 day

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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.

Experiments proper for the purpose.

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.

2dly, 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.

3dly, 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.

4thly, 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.

5thly, 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 impulsions. 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 experience is not the proper foundation of an axiom.

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.

31 Logical proof.

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, *2dly*, 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

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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.

It is a law of human thought,

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 rectilineal 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 rectilineal 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. 32

Vis insita, inherent force, are improper terms in their usual acceptation.

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.

But

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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

33 Motion is not the continual production of an effect.

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 reflecting 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.

34 Communication of motion is an improper phrase,

Kepler introduced a term INERTIA, VIS INERTIÆ, 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 inertiæ* 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 inertiæ*, 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.

35 So is *vis inertiæ*.

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

of

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 uniform rectilineal motion are the only indications 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 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 steelyard 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 of

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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.

38 Change of motion is, itſelf, a motion.

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.

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 rectilineal 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.

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.

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 poſſible 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.

41 How aſcertained and meaſured.

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 produceable 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.

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 expiſcate this; which we ſhall do, by conſidering the manner in which the motion of the ſhip is blended with each of the mens motions.

42 Compoſition of motion.

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.

The fundamental theorem on this ſubject is this:—Two uniform motions in the ſides of a parallelogram compoſe an uniform motion in the diagonal.

Plate XXI.

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.

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,

and

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and the point E is in the place *e*, the middle of GH. Draw E*e*L parallel to AC. It is plain that the parallelograms ABDC and AE*e*G 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 of AD. In like manner, it may be ſhewn, that when A has deſcribed AF, $\frac{3}{4}$ths of AB, the line AB will be in the ſituation IK, ſo that AI is $\frac{3}{4}$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, A*f* is deſcribed in $\frac{3}{4}$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 *e*H or AB; and, conſidered as a point of GH, it is moving in the direction *e*L. 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,

43 Its mark and meaſure.

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,

44 Changing force.

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,

Its effect.

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.

Deflecting force.

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.

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.

45 Fundamental theorem.

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.

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

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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 multifareous 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.

48
Objections to the demonstration of n° 45. It will not apply to pressures.

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 A *d*, opposite to AD, the pressure being also proportional to AD. This force, acting in the direction A *d*, 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 49.

that

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 φυ αν." 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 Peterſburgh. 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 Fonſenex, 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.

(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 AbCd (fig. A) be two rhombuſes, which have the common diagonal AC. Let the angles BAb, DAd, 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, gAh.

Draw GH, gh, 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, gh 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

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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 A *d*, greater than AD, be its just measure, and make A *d* : AB = AB : A *g* = AB : A *e*. Then A *g* and A *e* have the same inclination and proportion to AB that AB and AC have to A *d*. We determine, in like manner, two forces A *f* and A *g* as constituents of AC.

Now A *d* is equivalent to AB and AC, and AB is equivalent to A *e* and A *g*; and AC is equivalent to A *f* and A *g*. Therefore A *d* is equivalent to A *e*, A *f*, A *g*, and A *g*. But (A) A *e* and A *f* balance each other, or annihilate each other's effect; and there remain only the two forces or pressures A *g*, A *g*. Therefore (B) their measure is a magnitude equal to twice A *g*. But if A *d* be greater than the diagonal AD of the square, whose sides are AB and AC; then A *g* must be less than AI, the side of the square whose diagonal is AB. But twice A *g* is less than AD, and much less than A *d*. Therefore the measure of the equivalent of AB and AC cannot be a line A *d* greater than AD. In like manner, it cannot be a line A *δ* 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 : A *o*. Draw KOG, K *o g* perpendicular to AE, AF; draw GI *g*, OH *o*, EG, EK, F *g*, 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 A *g* and AK may compose the force AF. Therefore (B) the force AP is equivalent to the four forces AG, AK, A *g*, AK. But (D) AG and A *g* 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, A *g*, 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 $\frac{1}{8}$th, $\frac{1}{16}$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, A *b c d* (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 BA *b* and DA *d*.

The two forces AE, AF, compose a force AC.

Bisect AE and AF in O and *o*. Draw the perpendiculars GOH, *g o h*, and the lines GI *g*, OK *o*, HL *h*, and the lines EG, EH, F *g*, F *h*.

It is evident, that AGEH and A *g* F *h* are rhombuses; because AO = OE, and A *o* = *o* F. It is also plain, that since *b* A *d* is half of BAD, the angle GAH is half of *b* A *d*. It is therefore formed by a continual bisection of a right angle. Therefore (G) the forces AG, AH, compose a force AE; and A *g*, A *h*, compose the force AF. Therefore the forces AG, AH, A *g*, A *h*, acting together, are equivalent to the forces AE, AF acting together. But AG, A *g* compose a force = 2 AI; and the forces AH, A *h* 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 G *g*, O *o*, H *h*, 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*, 2 *a*, 4 *a*, &c. The proposition (H) is true of 3 *a*. In like manner, because (G) is true of 4 *a* and 8 *a*, proposition (H) is true of 6 *a*; and because it is true of 4 *a*, 6 *a*, and 8 *a*, it is true of 5 *a* and 7 *a*. 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 2 *a* 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 corrollary 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 all 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 deflecting 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.

52 Seeming difference of the compositions of motion and of pressure disappear when carefully examined.

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

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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—inſiſt, 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.

53 General corollaries.

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. 54.

2. The ſimple and the compound forces are proportional 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, n° 2.), they will form a triangle ſimilar to the triangle ABD. For the ſame reaſons they are proportional to the ſides of a triangle *a'b'd*, which are reſpectively perpendicular to their directions. 55.

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. 56.

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 57.

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with the sine of BAC contained between the directions AB and AC, and the sine of ADB is the same with the sine of CAD; also AB is to AC, or BD, as the sine of ADB (or CAD) to the sine 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

Plate XXII. 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.

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 ABLFKCD is a parallelopiped, 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 parallelopiped, compose a force having the proportion and direction of the diagonal.

61 One force may balance many acting together.

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.

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, A*h*, be in equilibrio, and let them be considered in the two parcels AB, AC, and AE, AG, A*h*; then AD is the equivalent of AB, BD (or AC), and DA is the equivalent of DF, FH, HA (or A*h*): 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. Expeditious methods for obtaining the resulting motion in complicated cases.

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 equatoreal 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 equatoreal 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.

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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 sloping 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.

Forces may be estimated by, or reduced to, 64 A given direction,

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.

65 Or a given plane.

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 *a b* drawn in that plane, and the other AD is perpendicular to it. The position of the line *a b* is determined by letting fall B *b* perpendicular to the plane, and drawing *b* P to the point P, in which BA meets the plane; then A *a* being drawn parallel to B *b*, will cut off *b a*, which is the reduction of the motion AB to the plane. Drawing AC parallel to *a b*, and completing the parallelogram ACBD, it is evident that the motion AB is equivalent to AD and AC, which is parallel to *a b*, and the three forces AB, AC, AD, are, as they should be, in one plane perpendicular to the plane EG.

66 Equilibrium of forces so estimated or reduced.

If three forces AB, AC, AD (fig. 11.), are in equilibrio, and are reduced to any one direction *d* A *l*, or to one plane EFGH, the reduced forces are also in equilibrio.

First, Let them be reduced to one direction *d l* 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, *d* A is equal to A *l*, and A *b* to C *o*, or to *c l*; therefore A *l* is equal to the sum of A *b* and A *c*, which are the reductions of AB and AC; therefore *d* A 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 δ, A α, B β C κ, L λ, are all parallel, being perpendicular to the plane; therefore the planes AB $\beta\alpha$ and CL $\lambda\kappa$ are parallel, and $\alpha\beta$, $\kappa\lambda$, are parallel. For similar reasons $\beta\lambda$, $\alpha\kappa$, are parallel; therefore $\alpha\beta\lambda\kappa$ is a parallelogram. Also, because the lines D δ, A α, L λ, are parallel, and DA is equal to AL; therefore $\delta\alpha$ 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 $\alpha\delta$ 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 $\alpha\delta$ is the reduction of AD; therefore the proposition is demonstrated.

The most useful mode of reduction to their co-ordinates.

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 co-ordinates. 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.

67 Relative motions of bodies not affected by any extraneous equal and parallel force.

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, is 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 *e c*, 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.

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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.

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 ſyſtem, 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.

So Bernoulli's defence of this laſt opinion is without force.

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 $\frac{1}{61}$ 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 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

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tinctly to every reader who is much converfant in difquifitions of this kind; and it is in thefe more moderate motions that the complete independence of the relative motions on the common motions moft accurately appears. Pendulum clocks and watches have been often executed which do not deviate from perfect equability of motion one part in 86400. This could not be obtained in all directions of the ofcillations, if the forces deviated from the ratio of the velocities one part in 86400.

Perfect agreement of the abftract notion of force with all our accurate obfervations of the exertions of natural powers.

On the whole, we may confider it as eftablifhed on the fureft foundation, that the action of thofe powers of natural bodies which we call *preffure*, fuch as the force of fprings, the exertions of animals, the cohefion of bodies, as well as the action of thofe other incitements to motion which we call *attractions* and *repulfions*, fuch as gravitation, magnetifm, and electricity—is proportional to the change of velocity produced by it. And we muft obferve here, that this is not a mere mode of conception, the refult of the laws of human thought, which cannot conceive a natural power as the caufe of motion otherwife than by its producing motion, and which cannot conceive any degree of *moving* power different from the degree of the motion. This is the abftract doctrine, and is true whether the preffures are proportional to the velocities or to the fquares of the velocities. But we fee farther, that whatever is the preffure of a fpring (for example) on a quiefcent body, yet the preffure actually exerted in producing a double velocity is only double, and not quadruple, as our firft imperfect obfervations make us imagine.

70
Newton's third law of motion is founded on experience alone, and is not a neceffary truth.

Sir Ifaac Newton has added another propofition to the number of laws of motion; namely, that *every action is accompanied by an equal and contrary reaction.* But in affirming this to be a law of nature, he only means that it is an univerfal fact: And he makes this affirmation on the authority of what he conceives to be a law of human thought; namely, that thofe qualities which we find in all bodies on which we can make experiments and obfervations, are to be confidered as univerfal qualities of body. But we have limited the term *law of motion* to thofe confequences that neceffarily flow from our notions of motion, of the caufes of its production and changes. Now this third Newtonian propofition is not fuch a refult. A magnet is faid to act on a piece of iron when, and only when, the vicinity of the magnet is obferved to be accompanied by certain motions of the iron. But it by no means follows from this obfervation, that the prefence of the iron fhall be accompanied by any motion, or any change of ftate whatever of the magnet, or any appearance that can fuggeft the notion that the iron acts on the magnet. When this was obferved, it was accounted a difcovery. Newton *difcovered* that the fun acts on the planets, and that the earth acts on the moon; and Kepler *difcovered* that the moon reacts on the earth. Newton had obferved that the iron reacts on the magnet; that the actions of electrified bodies were mutual; and that every action of fublunary bodies was, in fact, accompanied by an equal and contrary reaction. On the authority of his rule of philofophizing, he affirmed that the planets react on the fun, and that the fun is not at reft, but is continually agitated by a fmall motion round the general centre of gravitation. He pointed out feveral confequences of this reaction. Aftronomers examined the celeftial motions more narrowly, and found that thofe confequences do really obtain, and difturb all the planetary motions. It is now found that this reciprocity of action obtains throughout the folar fyftem with the utmoft precifion, and that the third Newtonian propofition is really a law of nature, although it is not a law of human thought. It is a difcovery. The contrary involves no abfurdity or contradiction. It would indeed be contrary to experience; but things might have been otherwife. It is conceivable, and poffible, that a ball A fhall ftrike another equal ball B, and carry it along with it, without any diminution of its velocity. The fact, that the velocity of A is reduced to one-half, is the indication of a force refiding in B, which force changes the motion of A; and the intenfity of this force is learned from the change which it produces. This *is found* to be equal to the change produced by A on B. And thus the reaction of B is *difcovered* to be equal to the action of A.

It is highly probable, that this univerfality and equality of reaction to action is the confequence of fome general principle, which we may in time difcover; meanwhile we are intitled to fuppofe it univerfal, and to reafon from this topic in our difquifitions about the actions of bodies on each other.

Maupertuis, Leibnitz, and other philofophers, have entertained very inadequate opinions concerning the foundation of the laws of motion.

Although the celebrated philofophers of Europe have at laft agreed in the reception of the two propofitions fo largely difcuffed by us as the laws of motion, they have differed exceedingly in their opinion about their origin and validity: Some afferted that they are entirely matters of experience; while others affirmed them to be neceffary truths. The royal academy of Berlin made this queftion the fubject of their prize differtation in the year 1744. Mr Maupertuis, prefident of the academy, publifhed a differtation; in which he endeavoured to prove that they are neceffary truths, only becaufe *they are fuch as make the quantity of action the leaft poffible* an economy which is worthy of infinite wifdom; and therefore certainly directs the choice of the Author of Nature. On this account alone are they neceffary truths.

But this is not the way to confider a queftion of this kind. We know too little about infinite wifdom to be able to fay with Meffrs Leibnitz and Maupertuis, that the Deity fhould or fhould not imprefs on bodies laws different from thofe which are effential to matter; and we are not to inquire whether God could or could not do this. We know from our own experience, that matter, when fubjected to the action of intelligence, may be moved in a way extremely different from what it would follow if left to itfelf, and that its motions may either be regulated by fixed, but contingent, laws, or may be without any conftancy whatever, and vary in every inftance. When we fuppofe the exiftence of matter and motion, a variety of truths are involved in the fuppofition, in the fame manner as all the theorems in the third book of Euclid's Elements are involved in the conception of a circle and a ftraight line. Our firft employment fhould be to evolve thofe truths. We can do this in no way but by firft noticing the relations of the ideas that we have of the different objects of contemplation, and then following the laws of human thought in our judgments concerning thofe relations. This procefs of the mind is expreffed in the train of a geometrical demonftration. The different parts or argu-

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mentations of this train are not the caufes of our conclufions, but the means by which we form our judgement; not the reafons of the truth of our ultimate conclufion, but the fteps by which we arrive at the knowledge of it. The young geometer generally thinks otherwife: But that this is the matter of fact is plain from this, that more than one demonftration, and often very different, can be given of the fame theorem. We muft proceed in the fame manner in the prefent queftion; and the firft general truths which we find involved in the notions of matter, motion, and force, muft be received as *neceffary* truths. The fteps by which we arrive at the difcovery are the laws of human thought; and the expreffion of the difcovery, involving both the truth itfelf and the manner of conceiving it, is a neceffary law of motion. There may be other facts, perhaps as general as any of thofe neceffary laws, but which do not neceffarily refult from the relations of our notions of motion and of force. Thefe are difcovered by obfervation only; and they ferve to characterife the forces which nature prefents to our view. Thefe facts are *contingent* laws of motion.

We apprehend that this method has been followed in treating this article. The firft propofition, termed *a law of motion*, is only a more convenient way of expreffing our contemplation of motion in body as an effect of the general caufe which we term *force*. The fecond propofition does nothing but exprefs more diftinctly the relation between this caufe and its effect; it expreffes what we mean by the magnitude and the kind of the caufe. The propofition, ftating the compofition of forces, is but another form of the fame law, better fuited to the ordinary procedure in geometrical difquifitions.

These propofitions might have completed the doctrines of dynamics; but it appears that, in order to the production of a material univerfe which fhould accomplifh the purpofes of the Creator, it was neceffary that there be certain characteriftic differences between the forces inherent in the various collections of matter which compofe this univerfe. The facts or phyfical laws (for the above-mentioned laws are metaphyfical) of motion may be different from thofe which would have been obferved had matter been left entirely to itfelf. This difference may have introduced other laws of motion as neceffarily refulting from the nature of the forces. We have occafionally mentioned fome inftances where this appears to obtain, but gave good reafons for affirming, that a due examination of all circumftances which may be obferved in the production or variation of motion by thofe forces, has demonftrated that there are no fuch deviations from the two laws of motion already determined, but that all the mechanical powers of bodies, when confidered merely as caufes of motion, act agreeably to the fame laws. Careful examination was, however, faid to be neceffary.

This examination muft confift in diftinctly noticing the circumftances that occur in the production of motion by any force whatever. It is by no means enough to ftate fimply the intenfity 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 intenfity or direction while it is acting, thefe circumftances muft induce ftill farther changes in the motion; and it is not till all action has ceafed that the motion is brought to its oftenfible ftate, in which it is the object of our attention and our future difcuffions. Inftances of the effects of fuch continued and fuch varied actions are to be feen in moft of the phenomena of nature or art. The communication of motion by impulfe is perhaps the only inftance (very frequent indeed) that can be produced where this is not neceffary: Nay, we fhall perhaps find reafon to conclude, that this inftance 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 fome time, and greatly varied during that time. Much preparation is therefore neceffary before we can apply the general laws of motion to the folution of moft of the queftions which come before us in the courfe even of our elementary difquifitions. We muft lay down fome general propofitions which determine the refults of the continued, and perhaps varied, actions of moving forces; and we muft mark the different effects of the fimple continuation of action, and alfo thofe of the variations in this continued action, both in refpect of intenfity and direction. The effect of a mere continuance of action muft be an acceleration of the motion; or a retardation of it, if the force continue to act in the oppofite direction. The effect of the continued action of a tranfverfe force muft be a continual deflection, that is, a curvelineal motion. Thefe muft therefore now occupy our attention in their order.

Of Accelerated and Retarded Motions.

Of Accelerated and Retarded Motions.

71 Circumftantial expofition of our conception of the condition of a body in refpect to motion.

All men can perceive, that a ftone dropped from the hand, or fliding down an uniform flope, has its motion continually accelerated, and that the motion of an arrow rifing perpendicularly through the air is continually retarded; and they feel no difficulty in conceiving thefe changes of motion as the effects of the continual operation of their weight or heavinefs. The falling ftone is in a different condition in refpect of motion in the beginning and the end of its fall. In what refpect do thefe ftates of the body differ? Only in refpect to what we call its *velocity*. This is an affection of motion; it is an expreffion of the relation between the two notions or ideas which concur to form the idea of motion; namely, the fpace and the time. Thefe are all the circumftances that we obferve in a motion. Time elapfes, and during its currency a fpace is defcribed. The term *velocity* expreffes the magnitude of the fpace which correfponds to fome unit of time. Thus, the rate of a fhip's motion is determined, when we fay that it is nine miles in an hour, or nine miles per hour. We fometimes fay (but aukwardly) "The motion is at the rate, or with the velocity, of a mile in three days." It is moft conveniently expreffed by a number of fome given units of length, which completely make up the line defcribed during this unit of time. But the mechanicians exprefs 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 feconds, minutes, or hours, employed in moving along this line. This is a very proper expreffion; for when we fpeak of any velocity, and continue to reafon from it, we conceive ourfelves to fpeak of fomething that remains the fame, in the different occafions of ufing the term. Now if the velocity be conftant, it is indifferent how

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 $\frac{48}{12}$, $\frac{36}{9}$, and $\frac{16}{4}$, are fractions of equal value, being equal to $\frac{4}{1}$, or 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:

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Momentary proportion of velocities that are continually changing. Fundamental requisite in all mechanical disquisitions.

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 *a c g* 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 *a c*, *c f*, *f g*, of the line *a g*, may represent the times employed in describing the portions AC, CF, FG; and therefore *a c* is to *a f* as the time of describing AC to the time of describing AF.

Moreover, let *h k n o* be a line so related to the straight line *a c f g*, by the perpendicular ordinates *a h*, *c k*, *f n*, *g o*, and the areas *a c k h*, *a f n h*, *a g o h*, 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 c k is to f n*.

Let the equal lines *b c*, *c d*, *e f*, *f g*, 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 *b i k c*, *c k l d*, *e m n f*, *f n o g*, will represent, and be proportional to, the spaces BC, CD, EF, FG, which are described during the moments *b c*, *c d*, *e f*, *f g*.

Draw *t p* parallel to *a g*, so as to make the rectangle *b t p c* equal to the trapezium *b i k c*; and draw the lines *q v*, *u r*, *s x*, in the same manner, so that each rectangle may be equal to its corresponding trapezium.

If the motions had been uniform during the moments *b c* and *f g*, 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 *c p* to *f s*: For since the rectangles *b t p c* and *f s x g* are respectively equal to the trapeziums *b i k c* and *f n o g*; and since *b i k c* is to *f n o g* as BC is to FG, the rectangle *b t p c* is to the rectangle *f s x g* as BC to FG. But because these two rectangles have equal altitudes *b c* and *f g*, they are to each other in the proportion of their bases *c p* and *g x*, or *c p* and *f s*. Therefore BC is to FG as *c p* to *f s*. But if BC and FG are uniformly described in equal times, they are proportional to the velocities of those uniform motions. Therefore *c p* is to *f s* as the velocity with which BC is uniformly decribed 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 *h l o* recedes from the axis *a g*, 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 *b c*, *c d*, *e f*, *f g*, 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 *c p* to *f s*. In the very same manner, it will appear by comparing the motion during the moment *c d* with the motion during the moment *e f*, 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 *f r*.

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 *f s*, but in a less ratio than that of *c q* to *f r*.

But by continually diminishing the equal moments *b c*, *c d*, *e f*, *f g*, it is evident that *c p* and *c q* continually approach to equality with *c k*; and *f r* and *f s*, continually approach to equality with *f n*, that when *c p* is less than *c k*, *f s* is greater than *f n*, and when *c q* is greater than *c h*, *f r* is less than *f n*.

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 *c k* to *any* line greater than *f n*, but which is less than the ratio of any line greater than *c k* to any line less than *f n*. Therefore the ratio of the velocity in C to the velocity in F is greater than any ratio that is less than that of *c k* to *f n*; but it is less than any ratio that is greater than that of *c k* to *f n*. Therefore the velocity in the point C is to the velocity in the point F as *c k* to *f n*.

This important theorem may be expressed in more general terms as follows:

If the abscissa a g *of a line* h k o *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 *a c g*, will, perhaps, appear more clearly in the following manner.

Let *a c g* be any straight line, and let *h k v* be another line, straight or curved. Let the straight line *a h z*, perpendicular to *a g*, be carried uniformly down along this line, keeping always perpendicular to it, and therefore always parallel to its first position *a h z*. In its various situations *c k z*, *e m z*, &c. it will cut off areas *a c k h*, *a e m h*, &c. bounded by the axis by the ordinates *a h* and *c k*, or by the ordinates *a h* and *c m*, &c. and by the line *h k g*. By this motion the moveable ordinate is said, in the language of modern geometry, to *generate* the areas *a c k h*, *a e m h*, &c. At the same time, let a point A move along the line ACG, setting out from A at the instant when the line *a z* 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, *a b*, *i h*, *a c k h*, *a d l h*, &c. or such that we shall have AB to AC as *a b i h*, to *a c k h*, &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 *a z*, along the axis *a g*, is supposed to be uniform, the spaces *a b*, *a c*, *a d*, &c. are proportional to the times in which they are described, and may therefore be taken to measure or to represent those times.

73. 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 *b c*, *c d*, *e f*, *f g*, 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 *c k* to *f n* is the limit of the continually increasing ratio of *c p* to *f s*, or of the continually diminishing ratio of *c q* to *f r*. Sir Isaac Newton calls this the ultimate ratio of *c p* to *f s*, or of *c q* to *f r*. Now the ratio of *c p* to *f s* is, by construction, the same with the ratio of the rectangle *b t p c* to the rectangle *f s x g*, and the ratio of *c q* to *f r* is the same with the ratio of the rectangle *c q v d* to the rectangle *e u r f*. But the ratio of the rectangle *b t p c* to the rectangle *f s x g* is the same with the ratio of the space *b i k c* to the space *f n o g*; that is (by hypothesis), the same with the ratio of the space BC to the space FG; and the ratio of the rectangles *c q v d* and *e u r f* 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 *c k* to *f n* is the limit both of the ratio of *c p* to *f s* and of the ratio of *c q* to *f r*, 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 *b i k c* to the area *e m n f* approaches more near to the ratio of *c k* to *f n* as we take the moments *b c* and *e f* 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 *c k* to *f n* 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.* 74.

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

the proportion of $\dot{s}$ directly, and of $\dot{t}$ inversely. We express this by the proportional equation $v \doteq \frac{\dot{s}}{\dot{t}}$, which is equivalent to the analogy $V : v = \frac{\dot{S}}{\dot{T}} : \frac{\dot{s}}{\dot{t}}$, or $V : v = \dot{S}\dot{t} : \dot{s}\dot{T}$.

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 $= \frac{\dot{y}}{\dot{x}}$.

The converse of this proposition may be thus expressed.

76 Converse theorem.

If the axis a g *of the line* h k o *represent the time of a varied motion along the line* AG, *and if the ordinates* a h, b i, c k, *&c. be as the velocities in the instants* a, b, c, *or in the points* A, B, C; *then the areas* a b i h, a c k h, a l l h, *&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 $a c k h$, $a f n h$, &c. they are proportional to some other areas $a c k h'$, $a f n' h'$, &c. which are bounded by the same ordinates, and by another line $h' k n'$. But because the areas $a c k h'$, $a f n' h'$, &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 $c k$ is to the ordinate $f n'$. But, by hypothesis, the velocity in C is to the velocity in F as $c k$ to $f n$, and $f n'$ is equal to $f n$; 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 $b c$, $e f$, are equal, it is evident that the ultimate ratio of the rectangles $b c p t$, $e f r u$ 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 $c p$ and $f r$; that is, the ratio of $c k$ to $f n$, 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, $\dot{S} : \dot{s} = VT : vt$, and $\dot{s} \doteq v\,\dot{t}$.

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 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.

78 A good example of the geometrical method.

This immediate observation of the analogy between 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 $a g$ 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 $a g$, we perceive that the line which comes in place of $h k o$ must be a straight line drawn from a. For example, the straight line $a \delta \gamma$. For this is the only boundary which will give areas $a b \beta$, $a c \kappa$, $a d \delta$, &c. proportional to $a b^2$, $a c^2$, $a d^2$, &c. And we perceive that *any* straight line drawn from a will have this property.

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 $a b$ is to $a d$; 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 $a b$ is to the time $a d$. 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 $\pi \kappa$ is to $\rho \phi$ as $b c$ to $d f$, &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 $\varepsilon \lambda$ parallel to the axis $a b$, we perceive that the rectangle $a e \varepsilon \lambda$ is double of the triangle $a e \varepsilon$. Now because $a e$ represents the time of the motion, and $e \varepsilon$ represents the acquired velocity, the rectangle $a e \varepsilon \lambda$ will represent the space which would be uniformly described with the velocity $e \varepsilon$ during the time 79.

$a e$.

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ae. But the triangle *ae* represents the space really described with 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 measureable 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 axample, 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 *a g o h*; 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 $\dot{s} = v\,\dot{t}$, 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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80. 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.

81 Measure of an accelerating force.

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.* (Another measure.)

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, and

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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
82 general theorem:

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.

83 Is an abſtract number.

Meaſure of a change of velocity.

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 meaſures expreſs the greateſt part of our knowledge of mechanical nature.

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 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.

84 Another meaſure of accelerating force.

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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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 $a = \frac{2\,s}{t^2}$.

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 B b, C c of AB and AC, and draw $b\,e$, $c\,f$ perpendicular to AD, and E h and F k 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

$$AD : AF = V^2, D : V^2, C. \quad \text{Therefore}$$
$$AE : AF = V^2, B : V^2, C.$$

But because in any uniformly accelerated motion, the spaces are as the squares of the acquired velocities, we have also

$$AE : A\,e = V^2, B : V^2\,b, \text{ and}$$
$$AF : A\,f = V^2, C : V^2\,c.$$

Therefore E e is to F f as the increment of the square of the velocity acquired in the motion along B b to the increment of the square of the velocity acquired along C c.

But, by similarity of the triangles ABD and E e h, we have

$$AB : AD = E\,e : E\,h; \text{ and, in like manner,}$$
$$AD : AC = F\,k : F\,f. \quad \text{Therefore}$$
$$AB : AC = E\,e \times F\,k : F\,f \times E\,h.$$

Now AB and AC are proportional to the forces which accelerate the body along the lines A'B and A'C; E e and F f are proportional to the increments of the squares of the velocities acquired in the motions along the portions B b and C c; and E h and F k are equal to those portions respectively. The ratio of AB to AC is compounded of the direct ratio of E e to F f; and the inverse ratio of E h to F k. The proposition is therefore demonstrated.

The proportion may be expressed thus:

$AB : AC = \frac{E\,e}{E\,h} : \frac{F\,f}{F\,k}$, and may be expressed by the proportional equation $AB \doteq \frac{E\,e}{E\,h}$ or, symbolically, $a \doteq \frac{(\dot{v^2})}{\dot{s}}$.

$\dot{v}\,\dot{v}$ is but one-half of the increment of v^2.

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 D d and B b be two moments of time, equal or unequal. Then D d e E and B b c C are half the increments of the squares of the velocities DE and BC, acquired during the moments D d and B b. It was demonstrated, that the ratio of the area D d e E to the area B b c C is compounded of the ratio of DE to BC, and the ultimate ratio of D d to B b. But D d and B b are respectively equal to $\epsilon\,e$ and $\kappa\,c$. Therefore D d e E is to B b c C, in the ratio compounded of the ratio of DE to BC, and the ultimate ratio of $\epsilon\,e$ to $\kappa\,c$. If we represent DE and BC by V and v, then $\epsilon\,e$ and $\kappa\,c$ 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 $v\,v'$; 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 $V\dot{V}$ to $v\,\dot{v}$. If, therefore, V^2 and v^2 represent the squares of the velocities, $V\dot{V}$ and $v\,\dot{v}$ 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 $a \doteq \frac{v\dot{v}}{\dot{s}}$; 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.

Measure of gravity considered as an accelerating force.

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-

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ty has generated the velocity 32 feet per ſecond by acting uniformly during one ſecond.

86. *The augmentation of the ſquare of the velocity is proportional to the force and to the ſpace jointly.* For, becauſe $a = \frac{\dot{v}\, v}{\dot{s}}$, we have $a\,\dot{s} = v\,\dot{v}$.

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.

Theorems reſpecting retarding forces.

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.

3. They are alſo as the ſquares of the times elapſed.

89. 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.

It 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 perhaps 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 abſciſſes of the triangle $a\,g\,v$. The ratio of $d\,\delta$ to $a\,d$ is the ſame with that of $e\,\varepsilon$ to $a\,e$, or that of $f\,\varphi$ to $a\,f$, &c.; or the ratio of the increment of velocity $\varpi\,\kappa$ to the increment of the time $\beta\,\varpi$ or $b\,c$, or that of $i\,\varphi$ to $\varepsilon\,i$, &c. This ratio $\varpi\,\kappa : \beta\,\varpi$ is equivalent to the ſymbol $\frac{\dot{v}}{\dot{t}}$

But when the ſpaces deſcribed in a varied motion are repreſented by the areas bounded by a curve line $h\,k\,o$, we no longer have that conſtant ratio of the increments of the ordinates and abſciſſes.

Therefore in order to obtain meaſures of the accelerating forces, or at leaſt of their proportions, let the abſciſſa $a\,e\,g$ (fig. 13.) of the line $h\,k\,o$ 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 $a\,g$ at the ſame rate with the velocities of the motion along the line AG. In this caſe the ordinates $b\,i$, $c\,k$, $d\,l$, &c. will be as the accelerations at the inſtants b, c, d, &c. or in the points B, C, D, &c. 90

Their meaſures in ſuch caſes how obtained? Theorems of moſt extenſive uſe.

This is demonſtrated in the ſame way as the former propoſition (n° 72.). If the accelerating force be ſuppoſed conſtant during any two equal moments $b\,c$ and $f\,g$, the rectangles $b\,c\,p\,t$ and $f\,g\,x\,s$ would expreſs the increments of velocity uniformly acquired in equal times, and their baſes $c\,p$ and $f\,s$ 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 $c\,p$ to $f\,s$; but, for ſimilar reaſons, it is in a leſs ratio than that of $c\,q$ to $f\,r$; and therefore (as in the other propoſition) the force at the inſtant c is to the force at the inſtant f as $c\,k$ to $f\,n$.

Cor. Becauſe $c\,p$ is to $f\,s$ in the ratio compounded of the direct ratio of the rectangle $c\,p\,t\,b$ to the rectangle $f\,s\,x\,g$, and the inverſe ratio of the altitude $b\,c$ to the altitude $f\,g$; 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: 91.

$$A : a = \frac{\dot{V}}{\dot{T}} : \frac{\dot{v}}{\dot{t}}.$$

Or by the proportional equation $a \doteq \frac{\dot{v}}{\dot{t}}$. Also $a \dot{t} \doteq \dot{v}$, and $\int a \dot{t} = v'$. 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 $a \doteq \frac{\dot{v}}{\dot{t}}$ 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 abscis, 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.

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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 accelerating force.

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.

But to return from this digression:

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More convenient manner of considering the action of forces, and more frequently coming into view.

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.

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 $o\,r$ 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 $f\dot{s}$, or to the ſymbol $\int fs$, uſed by the foreign mathematicians to expreſs this fluent, which they indeed conceive as an aggregate of ſmall rectangles fs'. And we ſee that this area expreſſes half of the augmentation of the ſquare of the velocity. Therefore,

95 Moſt important theorem (*Newton's Principia*, I. 39.)

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.

96. 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 BENφ, equal to the area BEIF, and then Bφ is the intenſity of the conſtant force wanted. In the ſecond caſe, in which the force EO is given, we muſt make the rectangle AαOE equal to the area BEIF, and AE is the ſpace required.

97 Converſe.

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 EIMe 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 (nº 85.). Now the baſe CG of the rectangle CDKG, is to the baſe EI of the rectangle EIMe in the ſame compounded ratio; therefore the force in C is to the force in E as CG to EI.

98 *Scales* of force, velocity, acceleration, time, &c.

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.

99. 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 FBEI as the ſquare of Ei to the ſquare of Cg (by conſtruction); but the area FBCG is to FBEI 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 × Ee = Cg × 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.

100 Examples of the application of nº 95.

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 φHN parallel to AB. The area BDHφ is to the area BENφ 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.

101 Example ſecond of peculiar importance.

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 AHa, cutting the ordinate EB in F; let eb be another ordinate, cutting the circle in f very near

to F; draw CH perpendicular to AC, and make the arch H h = f F, and draw h c parallel to HC; join FC and DH, and draw F g perpendicular to f b. 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 F f is diminiſhed continually, it is plain that the triangle f i F is ultimately ſimilar to CFB, by reaſon of the equal angles C i b (or CFB) and f i F, and the right angles CBF and f F i; therefore the triangles f g F and CBF are alſo ſimilar. Moreover, B b is equal to F g, F f is equal to h H, which is ultimately equal to c C; therefore ſince the triangles f g F and CFB are ſimilar, we have F g : F f = FB : FC, = FB : HC; therefore B b is to c C as FB to HC, that is, as the velocity at B to the velocity at C; therefore B b and c C are deſcribed in equal moments when indefinitely ſmall; therefore equal portions F f, h H, 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 h H is ultimately = C c. 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 C a, 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 AC a 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 AC a is the ſame with that of deſcribing AH a uniformly with the greateſt velocity. That is, to the time of deſcribing AC uniformly as AH a 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, B′E, a D′, lying on the other ſide of the axis AC a; 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.*)

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 AC a 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 $\frac{1}{4}$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 $\doteq \sqrt{a^n - x^n}$. 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 $\doteq x^{n-1}\dot{x}$, and the area is $\doteq x^n$; 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 $f \doteq \frac{v\dot{v}}{\dot{s}}$, 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 $A \times \overline{V^2 - v^2} = B \times \overline{u^2 - V^2}$, 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. $A \times \overline{V^2 - v^2}$ must exceed $B \times \overline{u^2 - U^2}$, 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.

History of nº 95. is curious.

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 matter;

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 $f\,\dot{s} = v\,\dot{v}$, 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.), $e\,f\,g\,h$, ſo related to their abſciſſes AD, $a\,d$, that the ordinates IK, $i\,k$, drawn from ſimilar points I and i of the abſciſſes, are in the conſtant ratio of AE to $a\,e$; then the area ADHE is to the area $a\,d\,h\,e$ as the rectangle of AD $\times$ AE to the rectangle $a\,d \times a\,e$.

For let each abſciſſa be divided into the ſame number of equal and very ſmall parts, of which let CD and $c\,d$ be one in each. Inſcribe the rectangles CGID, $c\,g\,i\,d$. Then becauſe the number of parts in each axis is the ſame, the lengths of the portions CD and $c\,d$ will be proportional to the whole abſciſſes AD and $a\,d$. And becauſe C and c are ſimilar points, CG is to $c\,g$ as AE is to $a\,e$. Therefore $\text{CD} \times \text{CG} : c\,d \times c\,g = \text{AD}$ $\text{AE} : a\,d \times a\,e$. 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 increaſed, and their breadth diminiſhed without end, it is evident that the ultimate ratio of the ſum of all the rectangles, ſuch as CDHG to the ſum of all the rectangles $c\,d\,h\,g$, is the ſame with that of the area ADHE to the area $a\,d\,h\,e$, and the propoſition is manifeſt.

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 $a\,b\,c$, and the forces by the ordinates AD, BE, CF, and $a\,d$, $b\,e$, $c\,f$. Then if B and b are ſimilar inſtants (ſuppoſe the middles) of the whole times, we have $\text{BE} : b\,e = \text{AD} : a\,d$. Therefore, by the lemma, the area ACDF is to $a\,c\,f\,d$ as $\text{AC} \times \text{AD}$ to $a\,c \times a\,d$. But theſe areas are proportional to the velocities (n° 72), and the propoſition is demonſtrated. For the ſame reaſon the change of velocity during the time AB is to the change during $a\,b$ as $\text{AB} \times \text{AD}$ to $a\,b \times a\,d$.

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 $a\,c$ are the ſpaces along which the particles are impelled, and the forces are as the ordinates AD and $a\,d$, the areas ACFD and $a\,c\,f\,d$ are as the changes on the ſquares of the velocities. But theſe areas are as $\text{AC} \times \text{AD}$, and $a\,c \times a\,d$. 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.) $a\,b\,c$ be the ſpaces deſcribed, and AD, $a\,d$, 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 $g\,h\,k$ 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° 99) Then, becauſe the forces act ſimilarly, we have, by the laſt theorem, $\text{AC} \times \text{AD} : a\,c \times a\,d = \text{V}^2, \text{B} : v^2, b, = h\,b^2 : \text{HB}^2$. Therefore $\text{HB} : h\,b = \sqrt{\overline{a\,c \times a\,d}} : \sqrt{\overline{\text{AC} \times \text{AD}}}$, and therefore in a conſtant ratio. Call this the ratio of m to n. But, ſince the ordinates of the lines GHK, $g\,h\,k$ are inverſely as the velocities, the areas are as the times (n° 99); and

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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

$$T : t = m AC : n ac \text{; and therefore}$$
$$T^2 : t^2 = m^2 \times AC^2 : n^2 \times ac^2. \text{ But}$$
$$m^2 : n^2 = ac \times ad : AC \times AD. \text{ Therefore}$$
$$T^2 : t^2 = ac \times ad \times AC^2 : AC \times AD \times ac^2,$$
$$\text{Or } T^2 : t^2 = ad \times AC : AD \times ac.$$
$$\text{Or } T^2 : t^2 = \frac{AC}{AD} : \frac{ac}{ad}.$$

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 $f \times \dot{t} = \dot{v}$. The second, $V^2 : v^2 = F \times S : f \times s$, is the extension of the theorem $f \times \dot{s} = v \dot{v}$. And the third, $T^2 : t^2 = \frac{S}{F} : \frac{s}{f}$, is the extension of $f = \frac{\dot{s}}{(\dot{t^2})}$, or of $f \times (\dot{t^2}) = \dot{s}$. These theorems hold true of all *similar* actions; and only for this reason, are true of uniformly accelerated motions, or uniform actions.

Aggregate of many equal accelerating forces.

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 immediatly 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 the force $m\frac{v}{t}$.

110 Moving force, motive force, vis motrix, as distinguished from accelerating force.

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 mv, 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 $= \frac{f}{m}\frac{v}{t}$.

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,

$$v = \frac{f}{mt},$$
$$vv = \frac{fs}{m}, \text{ or } v\dot{v} = \frac{f\dot{s}}{m}$$
$$t^2 = \frac{ms}{f}.$$

Of Deflecting Forces.

111 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 pro-

Of Deflecting Forces.

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 curvilineal motions.

We may almost venture to say *à priori*, that all deflections must be continual, or exhibit curvilineal 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.

112 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, ACGE. 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 subsultory, 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 curvilineal motion always arises from a composition of a uniform motion in the tangent with some transverse motion. But the same curvilineal 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 reside 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.

114 Newton's fundamental theorem for the direction of a deflecting force.

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 rectilineal motion is continually directed to the fixed point S.

Let

Of Deflecting Forces.

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 ∸ 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 (n° 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 $B\alpha$ and $F\epsilon$ 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.

118 Angular velocity is inversely as the square of the distance from the centre of forces.

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 $B\alpha$ and $F\epsilon$ 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 $B\alpha$ to $F\epsilon$, 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 $SE^2 : SB^2$.

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.

Intimate connection of dynamics and the higher geometry.

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 curvilineal 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.

Measure of curvature.

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

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 D*cba*. This geometrical operation is called the EVOLUTION of curves, and D*cba* is called the EVOLUTE of DCBA, which is called the INVOLUTE of D*cba*. 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 *b*B 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 *b*B, touches the circle *ebf* and the curve D*ba* in the point *b*. This circle *ebf* muſt lie within the curve D*ba* on the ſide of *b*B 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 *b*B. Therefore the circle *ebf* both touches and cuts the curve D*ba* in the point *b*. Moreover, becauſe every portion of the curve between *b* and D is deſcribed with radii that are ſhorter than *b*B, 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

Circle of curvature. Equicurve circle.

EQUICURVE CIRCLE, or the CIRCLE OF CURVATURE, and B is called the centre, and B*b* 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 *b*B. If *ib* be leſs than B*b*, it muſt fall within the curve on both ſides of *b*, and if *ib* is greater than B*b*, the circle muſt fall without the curve on both ſides of B*b*. 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.

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 D*ba* 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 D*ba* by evolution. See EVOLUTION and INVOLUTION, *Supplement*.

It is a matter worthy of remark, that the path of a body that is deflected from rectilineal motion by a *finite* 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 equilibrio in one ſingle point of its path.

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 B*b* of the parallelogram ABC*b* to the diagonal E*i* of the parallelogram DEF*i*; 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 B*b*. The triangles *b*BC and CBZ are ſimilar; for the angle C*b*B is equal to the alternate angle AB*b* or ABZ, which is equal to the ACZ, ſtanding on the ſame chord AZ. And the angle CB*b*, or CBZ, is equal to CAZ, ſtanding on the ſame chord CZ; therefore the remaining angle *b*CB is equal to the remaining angle AZC; therefore ZA is to AC as BC to B*b*, and B*b* $=\frac{AC \times BC}{AZ}$. In like manner E*i* $=\frac{DF \times EF}{Dz}$.

Now let the points A and C continually approach, and ultimately coaleſce with B; it is evident that the circle ABCZY is ulimately the equicurve or coinciding circle at the point B, and that AS ultimately coaleſces with, and is equal to, BS, and that AC × BC is ultimately $2BC^2$; therefore ultimately B*b* : E*i* = $\frac{2BC^2}{BZ} : \frac{2EF^2}{Ez}$, or $= \frac{BC^2}{\frac{1}{2}BZ} : \frac{EF^2}{\frac{1}{2}Ez}$.

Measure of deflecting forces.

Now BC and EF being deſcribed in equal times, are as the velocities: B*b* and E*i* 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 B*b* or E*i* is the third proportional to half of the chord and the arch deſcribed; for B*b* : BC $= BC : \frac{BZ}{2}$.

It is evident that as the arches AB, BC, continually diminiſh, AC is ultimately parallel to the tangent B*r*, 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

120 Measure of deflection.

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.

Caution.

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

a

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.* nº 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 $f \doteq \frac{\text{Arch}^2}{\frac{1}{4}\text{Chord}}$, or $f = \frac{2\,BC}{BZ}$. 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 $Bb^2 : BC^2 = Bo : x$; but $Bb : BC = BC : \frac{1}{4}BZ$; therefore $Bb^2 : BC^2 = Bb : \frac{1}{4}BZ$, and $Bb : \frac{1}{4}BZ = Bo : x$, and $Bb : Bo = \frac{1}{4}BZ : x$; but B *o* is $\frac{1}{2}$ of B *b*; therefore *x* is $\frac{1}{2}$ of BZ; that is,

121. *The velocity in any point of a curvilineal 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 curvilineal motion, which greatly aſſiſts us in our inveſtigations.

122 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 (nº 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 it 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.

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. 123 Retarded curvilineal 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 curvilineal 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 nº 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 rectilineal 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 curvilineal, when the accelerating force is transverse, in any degree whatever, to the projectile motion ; and the curvilineal 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 curvilineal, 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 (n° 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 F *d*, cutting the line DA in *d*. Then the velocity at A is to that at F as AB to *d* F. 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 n° 121. by the equicurve 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 recess 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 ? 125.

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 V *t* be the distance to which the body would go along the tangent VQ in the time T, and join *t* C. Let this be supposed done for every point of the curve. Let *a i k* and *a x y* 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 V *t* is known, and the area of the triangle VC *t*. But this is equal to the area VCI, by the laws of central forces (n° 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 *a i k*, *a x y*, the problem is solved as follows :

Draw an ordinate D *i*, 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 D *i 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 *a i k* and *a x y*, 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 (n° 73.). Describe the circle KE, cutting IC in N. Draw KC and *k* C, and *k n* perpendicular to VC.

The element ICK of the orbit is $= \frac{IC \times KN}{2}$, or to $\frac{1}{2}$ IC × KN. This is equal to the element D *i k* E of the area V *a i* D, or to D *i* × DE, or to D *i* × 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

that is (n° 86.), let $V l^2$ be to $D f^2$ as ABLV to ABFD, or $V l : D f = \sqrt{ABLV} : \sqrt{ABFD}$. 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 $m r z$ be an equilateral hyperbola, having VC, ZC, for its assymptotes, 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 VCk and ICK are equal, $k n : KN = CI : CV$. Therefore,

$$V m : D r = k n : KN$$

but $\quad V v : V m = V k : k n$

and $\quad I i \text{ (or } D f) : V v = IK : V k$

therefore $\quad I i : D r = IK : KN$

but $\quad I i : i o = IK : KN$, by sim. triang.

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

$$2 IN : KN = IC : D i$$

or $\quad 2 I o : i o = IC : D i$

but $\quad i o : V m = VC : IC$

therefore $\quad 2 I o : V m = VC : D i$

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 XCY 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 $= I i^2 - i o^2 = D f^2 - D r^2$, and $I o = \sqrt{D f^2 - D r^2}$. Moreover, $D f^2 = ABFD$, 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 centripetel 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 $a b - \int y \dot{x}$ may represent the indeterminate area ABFD.

We have $D i = \frac{a c}{2 \sqrt{a b - \int y \dot{x} - \frac{a^2 c^2}{x^2}}}$

and $D x = \frac{a^3 c}{2 x^2 \sqrt{a b - \int y \dot{x} - \frac{a^2 c^2}{x^2}}}$

Remark. We have hitherto supposed that the velocity of projection is acquired by acceleration along AV. But this was merely for greater simplicity of argument, 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 $\sqrt{a b - \int y \dot{x}}$.

126. *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 $= \frac{a c}{x \sqrt{a b - \int y x}}$.

127. Apsides determined; *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.

128. And curvature. *Cor.* 3. The curvature of the orbit VIK 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 deflective chord of the equicurve circle, 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.

129. Newton the inventor. 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 mathesi 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.

130. History of this problem. 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 for

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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 curvilineal 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 Horseley (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 curvilineal 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 Pieridum peragro loca, nullius ante*
> *Trita pede* ——

Singular boast of John Bernoulli.

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, $\frac{ac}{\sqrt{ab - \int \varphi \dot{x} - \frac{a^2c^2}{x^2}}}$ and $\frac{a^2c}{\sqrt{abx^4 - \int \varphi x^4 - a^2c^2x^2}}$; which last is plainly the same with Newton's $\frac{Q \times CX^2}{A^2\sqrt{ABDF - Z^2}}$; because Newton's $\frac{Q}{A}$ is the same with $\frac{a\varphi}{x}$, and Newton's $A^2\sqrt{ABFD - Z^2}$ is the same with $x^2\sqrt{ab - \int \varphi \dot{x} - \frac{a^2c^2}{x^2}}$, which Bernoulli has changed (apparently to hide the borrowing) into $\sqrt{abx^4 - \int \varphi x^4 \dot{x} - a^2c^2x^2}$. 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 knowlege 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 *now* 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

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 diſpleaſed 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 derived 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 etherial 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;

Utque 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 profeſſes to involve no notions but thoſe of force, and its 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.

134 Univerſal reaction is a law of the material world. 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.

135 Impulſion explained by it; Availing ourſelves of this fact, we, with very little trouble, ſtate all the laws of impulſion. The body A, for example, moving to the weſtward at the rate of 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 equilibrio."

This is almost self-evident; for if these second constituent forces be not such as would put the system in equilibrio, the other constituent motions could not be those which the bodies really take by the mutual action, but would be changed by the first.

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, and 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 κ. 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 κ. Now by the supposition, the bodies actually take the motions a, b, and c; therefore the motions α, β, and κ, must be such as will not derange the motions a, b, and c; that is to say, that if the bodies had only the motions α, β, and κ, 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 equilibrio; 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 equilibrio, 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 139. 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.

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 fidendum.*" 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 $\frac{f v s}{m}$ 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 $\dot{s}$, and that f is the same with $m\dot{v}$.

Great advantages of the geometrical method.

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 later 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.*

 DYN

Dynanometer.

DYNANOMETER, 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 Desaguliers; 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 Dynanometer than Graham's, consisting of a metal tube, 10 or 12 inches

Dynanometer. 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 *dynanometer;* and the account which he gives * of his attempts to fulfil their wiſhes is calculated to enhance the difficulty of the enterprize. 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.

* *Journal de l'Ecole Polytechnique*, v. 2.

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. 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. 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.

E.

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.

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

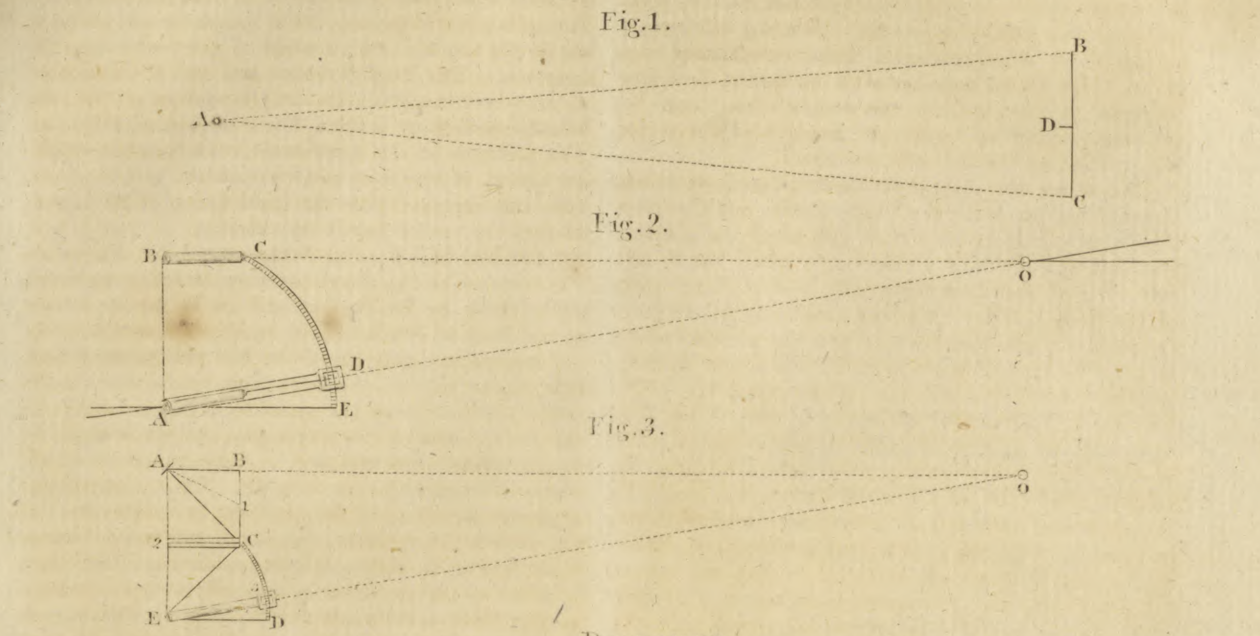
Fig.1.
Fig.2.
Fig.3.

DYNAMICS

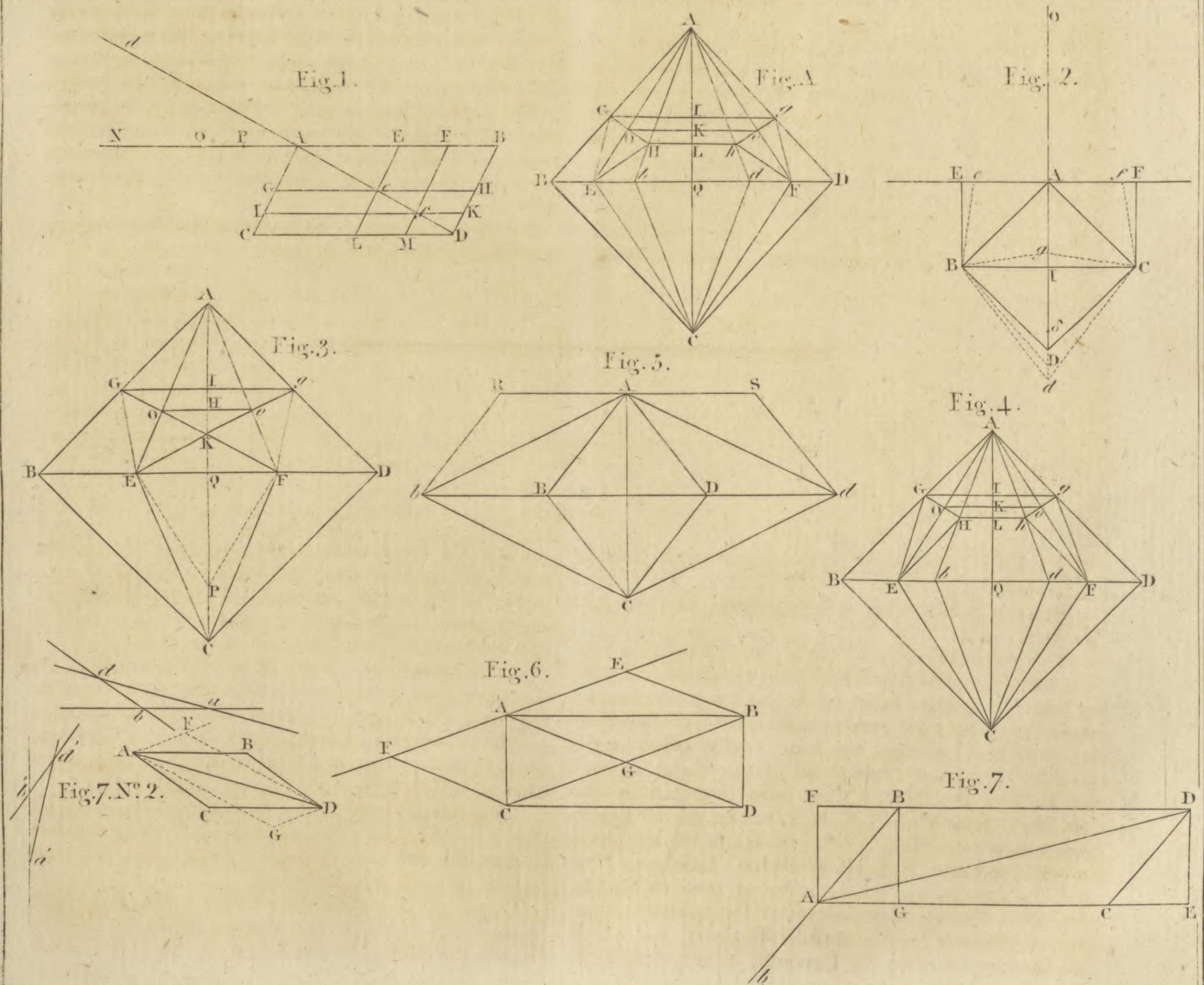
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Fig. 8.

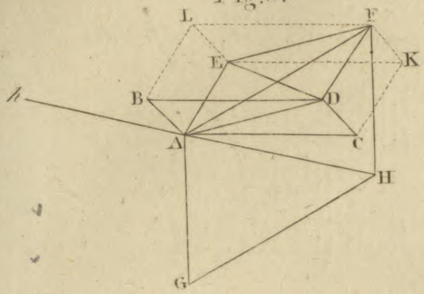
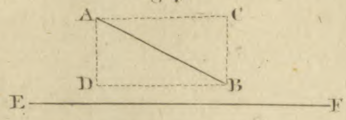


Fig. 9.



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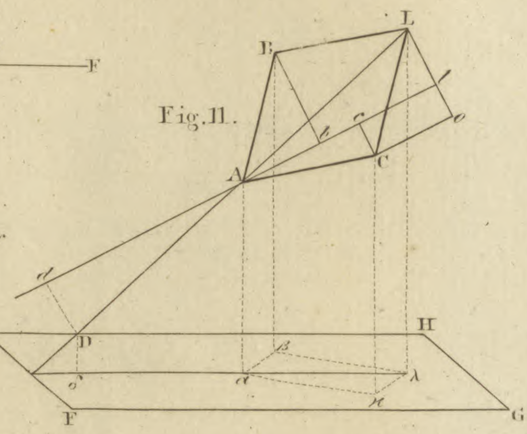


Fig. 12.

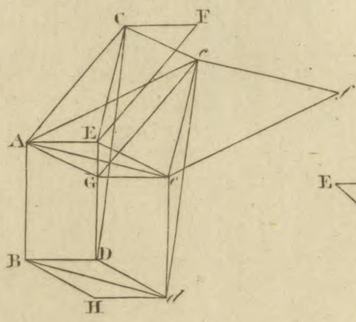


Fig. 10.

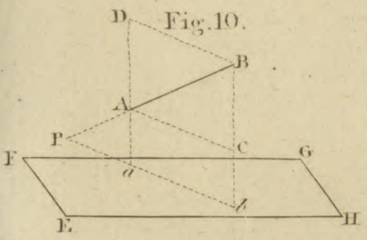
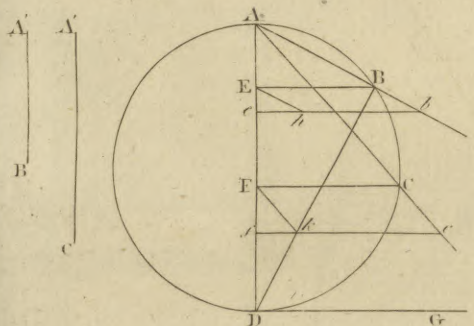


Fig. 14.



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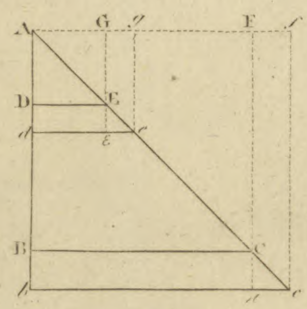


Fig. 13.

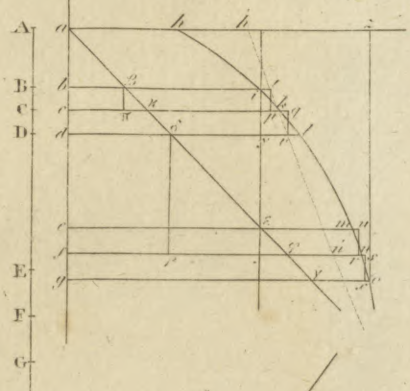


Fig. 17.

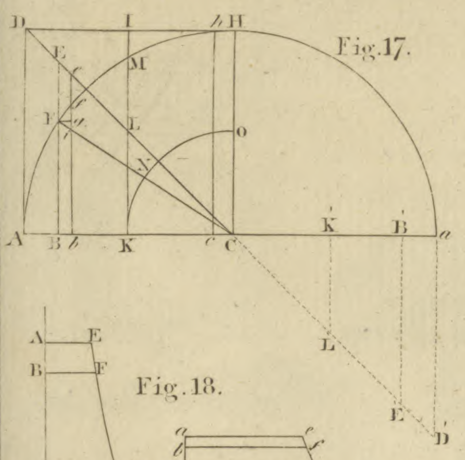


Fig. 16.

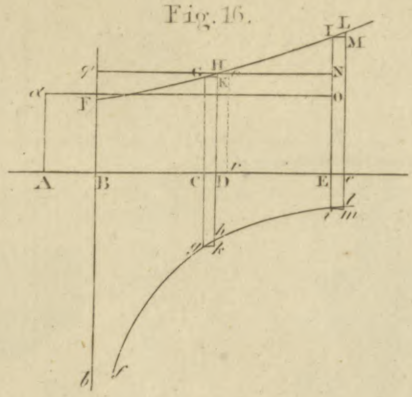
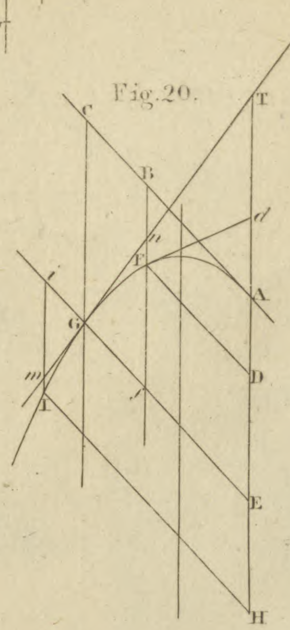


Fig. 20.



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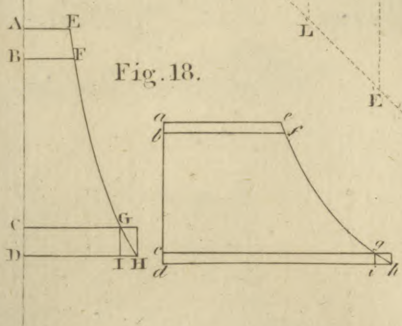
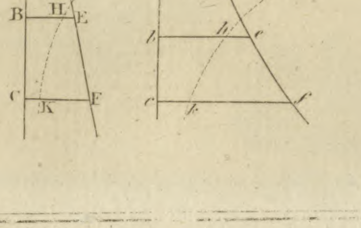
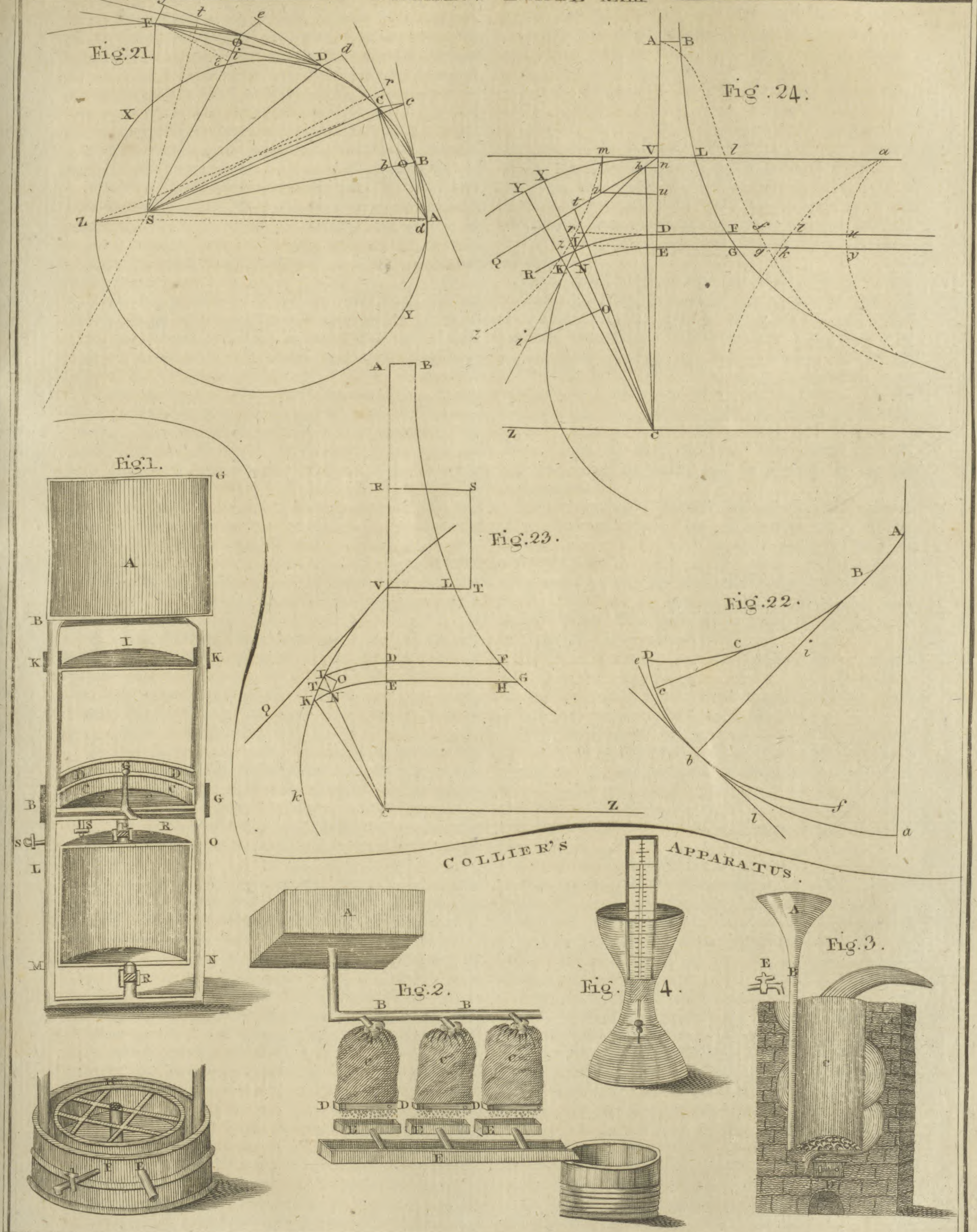


Fig. 19.





D. Lizars Sculpt.

Earth.

casioned 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 cieling, 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 Schehallien, 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 Petersburgh. 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 violent 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.

Earth, Eau de luce.

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° 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 opake 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 featheredged 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° 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.

Ecliptic, Edyſtone.

EDYSTONE Rocks, ſo remarkable for the lighthouſe 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 *Ramhead* 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 ſouthweſt come uncontrouled upon the Edyſtone rocks, and break on them with the utmoſt fury.

Smeaton's Account of the Edyſtone Light-houſe.

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 *ſloping* 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 *groundſwell*, 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 in 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 ſurpriſe. 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.

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 overſet; 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 jambed 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 the

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 highest 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 terminated 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 highest 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-six 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. Reflecting 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 *waist*, 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 waist 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 mass 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 was overset 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. Edyſtone.

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 occasion

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 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 tinners (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 tinners 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 20d. and the tinners 18d. 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 2s. 6 d. and the ordinary men 2s. 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 10s. 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 Indiaman 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 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 buſs. After overcoming many difficulties, the buſs 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 venture

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, inſomuch 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 buſs, 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, windlaſs, &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 buſs 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 appeared 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 ſought 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 buſs. On the following day, the air being more clear, he had a diſtinct view of the building; but the buſs 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 buſs 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 buſs 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 buſs'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 copperſmiths. 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 conſiſted 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 buſs 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 ſurpriſe.

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 Hoa, 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;

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 frighted 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 notion 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 downfal 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° 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 accompaniment 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 Peterſburgh. This gentleman,

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 Electritatis 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 embaraſſments; 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 of peculiar nature, and therefore called the electric fluid, having the following properties: 1 Hypotheſis.

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, roſins, 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; 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. 5.

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. Plate 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 quantity, why ſo called.

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° 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 common 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.

10 Electric phenomena ariſe from redundancy or deficiency in fluid, total or partial.

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.

11 Action of the redundant fluid or matter, how computed.

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. It is attracted by the common matter of the body (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 $Q : Q + f = r : \frac{\overline{Q+f} \times r}{Q}$; and therefore P is repelled by the whole fluid with the force $\frac{\overline{Q+f} \times r}{Q}$, 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

12 States of a body causing efflux or influx.

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.

13. 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 $\frac{\overline{Q-f}\times r}{Q}$ $= r - \frac{fr}{Q}$. It is attracted with the force a; and therefore 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° 10, that *the action of a body on the electric fluid depends entirely on the redundant fluid, or the redundant matter of the body.*

14 How bodies are ideo-electrics or non-electrics.

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.

15 Consequences of unequable distribution of fluid. 1. Action on external fluid.

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 unsaturated, and such as will attract fluid as much as the quantity g 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 $a - \frac{\overline{Q+f}\times r}{Q}$ $- \frac{\overline{Q-g}\times r'}{Q}$. But because $a - r - r' = 0$, the action becomes $= \frac{gr' - fr}{Q}$, or because r is greater than r', the particle N is repelled with the force $\frac{fr - gr'}{Q}$. In like manner the particle S is attracted with the force $\frac{gr - fr'}{Q}$.

16 2. Action on the contained fluid.

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 overchar-

ged

ged with the quantity f, C must be repelled in the direction CS with the force $\frac{fr}{Q}$. And if we also suppose that AS is deficient by the quantity g, C is attracted in the direction CS with a force $\frac{gr}{Q}$. Therefore, on the whole, it is urged in the direction CS with the force $\frac{fr+gr}{Q}$, or $\frac{\overline{f+g}\times r}{Q}$.

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.

18 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 $\frac{f\times\overline{r+r'}}{Q}$, which is much greater than $\frac{fr-gr'}{Q}$. 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.

22 A body may be inactive, or neutral, where it is redundant or deficient.

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 to their opposite. Thus, in order that there may be no tendency to escape from N, we have only to suppose $gr'-fr=0$, or $g:f=r:r'$, and $g=\frac{fr}{r'}$. 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.

23 Conditions necessary for this.

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 $\frac{fr}{r'}$ in place of g in the formula $\frac{gr-fr'}{Q}$, which expresses the attraction for a particle at S, and we obtain $\frac{f\times\overline{r^2-r'^2}}{Qr'}$.

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 $g=\frac{fr'}{r}$. When this obtains at S, the action at N will be had by putting $\frac{fr'}{r}$ in place of g in the formula $\frac{fr-gr'}{Q}$, and this will give us $\frac{f\times\overline{r'^2-r^2}}{Qr}$ for the force repelling a particle at N. 24.

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 appartus 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 $\frac{fr}{r'}$. If, on the contrary, g be greater than $\frac{fr}{r'}$, the extremity N, tho' overcharged, will attract fluid. In like manner, if g be 26.

be less than $\frac{fr'}{r}$, the extremity S, although undercharged, will repel fluid.—We may make the following general remarks.

27 Both ends cannot be neutral at once.

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 $\frac{(fr - gr' + hr'' - ir''')}{Q}$, &c.

29 Sensible actions of electrical bodies.

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, because 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. 30.

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 $+ Fmz$
2. F tends *from f* with the force $— Ffz$
3. M tends *toward f* with the force $+ Mfz$

Therefore the sensible tendency of A to or from B will be $= z \times \overline{Fm + Mf - Ff}$. 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 Fmz is balanced by the repulsion Ffz. 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 Mfz, or B attracts A with the force Mfz. A must therefore move toward B. And, by the 3d law of motion, B must move toward A with equal force.

31 Completion of the hypothesis of Æpinus.

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 $= z \times \overline{Fm - Ff - Mm + Mf}$. Fmz is balanced by Ffz, and Mmz by Mfz, and no excess remains on either side.

32 Objections answered.

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,

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, niſus 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 nº 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 tangible 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. 33 General expreſſion (ſymbolical) of the mutual action.

2. In like manner, two bodies A and B, containing the redundant matter M' and m', will repel each other with the force $M'\,m'\,z$. 34.

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 $F\,m'\,z$. 35.

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. 36.

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. 37 Seeming paradox.

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 38 Action of a body having the fluid unequably diſpoſed.

pends 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 *s*, and is crowded into B *n*. 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 $F' f' \times \overline{z - z'}$.

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 $F' f' \times \overline{z - z'}$.

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.

39 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.

40 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 *s* 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 41.
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.

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° 21, 22, 23, 24. When theſe things are attended to, we ſhall explain, with great eaſe, all the curious phenomena of the electrophorus.

42 Neutrality generally limited to a preciſe diſtance. Important information obtained from this.

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 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.

43 Action when the fluid is unequably diſpoſed in both bodies.

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.

Firſt,

First, then, let the overcharged end of A (fig. 5.) fron 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 in *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 attractions 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 $\frac{F' f' (Z - Z' - z + z'}{F f}$.

Useful representation of the mutual forces by ordinates to a curve.

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 C *z*, take C *p* = N *s*, C *q* = N *n*, C *r* = S *s*, and C *t* = S *n*, and erect the ordinates P*p*, Q*q*, R *r*, and T *t*. 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 PQRTZ, 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.

45 General character of the scale of electric force.

This construction evidently makes the pair of ordinates P *p*, Q *q*, equidistant with the pair R *r*, T *t*. Also, P *p*, R *r*, and Q *q*, T *t*, are equidistant pairs. It is no less clear, that the sum of P *p* and T *t* exceeds the sum of Q *q* and R *r*. For if C *z* be bisected in V, and V *v* be drawn perpendicular to it, cutting the straight lines PT and QR in *x* and *y*, then *x v* is the half sum of P *p* and T *t*, and *y v* is the half sum of Q *q* and R *r*. Moreover, if Q *m* and T *n* are drawn parallel to the base, we see that P *m* exceeds R *r*; and, in general, that if any pair of equistant 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 $P p + T t$ is greater than $Q q + R r$. 46.

Secondly, This attraction must increase by bringing the bodies nearer; for this will increase the difference between P *m* and R *n*. 47.

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 *q t*, R *r* is more diminished than T *t* is. In like manner, by increasing B, whose length is represented by *p q* or *r t*, we diminish Q *q* more than T *t*. 48.

49 Use of this picture of the forces.

On the other hand, if the overcharged end of B front the overcharged end of A, their mutual action will be $\frac{F' f' (-P p + Q q + R r - T t),}{F f}$ 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.

50 Curious phenomena which should result from the hypothesis resembling magnetism.

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

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 conſtipated 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 $F' f i \times (z - z')$.

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 attracts 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 conſtipate 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

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 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.

Neutral point.

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 under-

charged

charged in its nearer fide, and lefs undercharged in its remote fide than if B were taken away. This muft increafe the inequability of diftribution of the fluid in B, and both will be put farther from their natural ftate; but A will never become overcharged in its remote extremity.

Things being in this ftate, it is plain that A and B will mutually attract each other in the fame manner, and with the fame force, as when A was as much overcharged as it is now undercharged.

54 Electric atmofphere is not adequate to the explanation of the phenomena.

Thus, then, we fee how the attraction obtains, whether A be over or undercharged. A fact which Dr Franklin could never explain to his own fatisfaction; nor will it ever be explained confiftently with the acknowledged principles and obferved laws of mechanics by any perfon who employs elaftic atmofpheres for this purpofe. It is indeed a fufficient objection to the employment of fuch electric or other atmofpheres, that the fame extent of attraction and repulfion between the particles of the atmofphere is neceffary, as is employed here between the particles of the fluid refiding in the body; and therefore they ceafe to give any explanation, even although their fuppofed actions were legitimately deduced from their conftitution. This is by no means the cafe. Let any perfon examine ferioufly the *modus operandi* of the electric atmofpheres employed by Lord Mahon (the only perfon who has written mathematically on the fubject), and he will fee that the whole is nothing but figurative language, without any diftinct perception of what is meant by thefe atmofpheres, as diftinct from the fluid moveable in the conducting bodies, or any perception how the unequal denfity of thefe atmofpheres protrudes the fluid along the conductor. Befides, it is well known that a conducting wire becomes pofitive at one end, and negative at the other, by the mere vicinity of an overcharged or undercharged body, and this in an inftant, although it be furrounded with fealing-wax, or other non-conductors, to any thicknefs: in this cafe there can be no atmofpheres 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 filk line, without any fenfible diminution of its electricity. It is not conceivable that an electric atmofphere could remain attached to the ball; nor could it be inftantaneoufly formed round the ball, in every point of its motion, fo as to be operative the moment he ftopped it and tried it; for this would have exhaufted or greatly diminifhed the electricity of the ball); whereas that fagacious philofopher affirms (and any perfon will find it true), that when the air is dry, he did not obferve the electricity more diminifhed than that of another ball which remained all the while in the fame 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 ftate, and lying parallel to each other; the fluid will be propelled toward their remote ends N, *n*, where it will be condenfed, 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 *n* C; and the redundant matter in SB will repel the redundant matter in *s* C. For this reafon the bodies B and C will repel each other, and will feparate; but SB attracts *n* C, and NB attracts *s* C; and on this account the bodies fhould approach: but the diftances of the attracting parts being greater than thofe of the repelling parts, the repulfions muft prevail, and the bodies muft really feparate.

It is equally clear that the very fame *fenfible* appearance will refult from bringing an undercharged body near the ends of B and C, although the internal motions are juft the oppofite to the former.

If another body D, electrified in the fame way with A, be brought near the oppofite ends of B and C, it will prevent or diminifh the internal motions, and it fhould therefore prevent or diminifh 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 cafe with the body F, it will attract this remote end. As the body A, containing more or lefs than its natural fhare of electric fluid, affects every other body, while they do not (when out of its neighbourhood) affect each other, it is ufually faid to be the electrified body, and the others are faid to be electrified by it; and fince thefe bodies, when perfect conductors, cannot retain their power of exhibiting electrical appearances (fee n° 17.), it will be convenient to diftinguifh this laft electrical ftate by a particular name. We fhall call it ELECTRICITY BY POSITION, or INDUCED ELECTRICITY. It is induced by pofition with regard to the permanently electrical body.

We have fuppofed, in thefe laft propofitions, that the fluid was perfectly moveable in B, and, at laft, alfo, in A: but let us examine the confequences of fome obftruction to this motion. 56 Confequences of obftructions. Without entering into a minute enquiry on this head, we may ftate the obftruction as uniform, and fuch that a certain fmall force is neceffary for caufing a particle of fluid to get through between two particles of the common matter, juft as we conceive to happen in tenacious bodies of uniform texture (fee n° 18.).

It is evident, that when an overcharged body A (fig. 4. or 5.) is brought near fuch an imperfect conductor B, the fluid cannot be fo copioufly propelled to the remote extremity *n*. We may conceive the ftate of diftribution by taking a conftant quantity from the intenfities of the force of A at every point of B. This circumftance alone fhews us that there will not be fo unequable a diftribution of the fluid, and therefore *there will not be fuch a ftrong attraction between imperfect as between perfect conductors.* But befides this, we fee that an incomparably longer time muft elapfe before things come to a ftate of equilibrium. Each particle of fluid employs time to overcome the obftacle to its motion, and it cannot advance till after the fucceeding ones, each efcaping in its turn, have again come up with the foremoft. An important confequence refults from this. The neutral point, where the fluid is of the natural denfity, will not be fo far from the other body as it would have been without thefe obftructions; and this point will be a confiderable while of advancing along the imperfect conductor. At the firft 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 fmall way, the difplaced fluid being crowded a little before it, and giving way by degrees as 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 diſtribution.

There is another remarkable conſequence of the obſtruction. It muſt always happen that, at the beginning of the action, the greateſt conſtipation will not be towards the remote extremity, but in a place much nearer to the diſturbing cauſe. Beyond this, the conſtipation will diminiſh. As time elapſes during this operation, this conſtipated 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 conſtipation 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.

Several neutral points.

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.

58 Induced electricity, rendered permanent.

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 equable 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, 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.

59 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° 14. and we recommend the caſe to the attentive conſideration of the reader. 60 Electrics are only ſuperficially ſo.

61 Compariſon of the theory with experiment.

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

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:

62
Apparatus neceſſary for this compariſon.

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. 63

63
A neutral body attracted, becauſe rendered electrical by induction.

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.

State of diſtribution aſcertained experimentally.

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 always

Lord Mahon's determination of the neutral point not warranted by his explanation.

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 juxta-poſition 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° 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.

65 In the induction of electricity nothing is communicated. Inherent powers are excited.

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

palm 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.

66 The forced disposition of fluid is affected by other electrified bodies.

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° 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.

Electric needles polarity and verticity.

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 conductor 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. 67

Phenomena of imperfect conductors greatly corroborate the theory.

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.

Irregularities. 68

We need not go over the same ground again with imperfect conductors. It is well known that such bodies

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-filings 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.

70 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.

71 Electricity by communication

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.

Muſt happen abruptly.

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 *ſaltus* 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 encreaſed in a certain abrupt degree.

* *Opuſcles de d'Alembert*, t. I. 257.

72. Theſe obſervations muſt ſuffice at preſent to explain the deſultory nature of this tranference, 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.

73 Imparted electricity produces mutual repulſion.

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 ſudenly 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 ſaltneſs, 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. Transference of a peculiar ſubſtance highly probable.

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.

74 Degrees of vivacity proportioned to the quantity imparted.

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 encreaſed, 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.

75 Communication moſt remarkable in conductors.

2. All the phenomena of communicated electricity muſt be more remarkable in proportion to the conducting power of the bodies. A very imperfect conductor,

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 appearances.

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 and then repels any unelectrified 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 80 Electric action, like gravitation, is not hindered by the interposition of non-conductors.

of

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, $F' m' \times \overline{z - z'}$; 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 Hauſen, 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 com-

communicating bodies is always confiderable. It appears to keep fome fettled ratio to the whole electric power of the body. When the form of the parts where the communication takes place, and other circumftances, remain the fame, the transference increafes with the fize of the bodies; and all the phenomena are more vivid in proportion. When the conductor is very large, the fpark is very bright, and the fnap very loud.

Snap,

1. This fnap alone indicates fome material agent. It is occafioned by a fonorous undulation of the air, or of fome elaftic fluid, which fuddenly expands, and as fuddenly collapfes again. But fuch is the rapidity of the undulation, that when it is made in clofe veffels it does not exift long enough, in a very expanded ftate, to affect the column of water, fupported in a tube by the elafticity of the air, for the purpofe of a delicate thermometer or barometer; juft as a mufket ball will pafs through a loofe hanging fheet of paper without caufing any fenfible agitation.

Spark, and heat.

2. The fpark is accompanied by intenfe heat, which will kindle inflammable bodies, will melt, explode, and calcine metals.

Chemical effects.

3. The fpark produces fome very remarkable chemical effects. It calcines metals even under water or oil; it renders Bolognan phofphorus luminous: It decompofes water, and makes new compofitions and decompofitions of many gaziform fluids; it affects vegetable colours; it blackens the calces of bifmuth, lead, tin, luna cornea; it communicates a very peculiar fmell to the air of a room, which is diftinct from all others; and in the calcination of metals, it changes remarkably the fmells with which this operation is ufually accompanied: it affects the tongue with an acidulous tafte; it agitates the nervous fyftem.—When we compare thefe appearances with fimilar chemical and phyfiological phenomena, which naturalifts never hefitate in afcribing to the action of material fubftances, transferable from one body, or one ftate of combination, to another, we can fee no greater reafon for hefitating in afcribing the electric phenomena to the action of a material fubftance; which we may call *a fluid*, on account of its connected mobility, and *the electric fluid*, on account of its diftinguifhing effects. We are well aware, that thefe evidences do not amount to demonftration; and that it is poffible that the electric phenomena, as well as many chemical changes, may refult from the mere difference of arrangement, or pofition, of the ultimate particles of bodies, and may be confidered as the refult of a change of modes, and not of things. But in the inftances we have mentioned, this is extremely improbable.

This is therefore affumed.

We therefore venture to affume the exiftence of this fubftance, which philofophers have called *the electric fluid*, as a propofition abundantly demonftrated; and to affirm, on the authority of all the above-mentioned facts, that its mechanical character is fuch as is expreffed in Mr Æpinus's hypothefis.

We proceed, therefore, to explain the moft interefting phenomena of electricity from thefe principles.

84
Diftribution of it depends on its law of action.

We have feen that, in a perfect conductor, in its natural ftate, the electric fluid is uniformly diftributed, and cannot remain in any other condition. We are particularly interefted to know how it is diftributed 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 efcape, and particularly the tendency to transference from one body to another, muft be greateft where the fluid is moft conftipated. We know that it tends remarkably to diffipate from all protuberances, edges, and long bodies, and that it is impoffible to confine it in a body having very acute far-projecting points; and, what is more paradoxical, it is hardly poffible to prevent its entering into a body furnifhed with a fharp point. The fmalleft reflection muft fuggeft to our imagination, that a perfectly moveable fluid, whofe particles mutually repel, even at confiderable diftances, and which is confined in a veffel from which it cannot efcape, muft be compreffed againft the fides of the veffel, and be denfer there than in the middle of the veffel. But in what proportion its denfity will diminifh as we recede from the walls of the veffel, muft depend on the change of electric repulfion by an increafe of diftance. The intenfity varies in the proportion of fome function of the diftance, and may be expreffed by the ordinates of a curve, on whofe axis the diftances are meafured. But we are ignorant of this function. We muft therefore endeavour to difcover it, by obferving a proper folution of phenomena. Having made fome approximation to this difcovery, fuch as fhall give rife to a *probable conjecture* concerning the function which expreffes the intenfity of electric repulfion, mathematics will then enable us to fay how the fluid muft be diftributed (at leaft in fome fimple and inftructive cafes) in a perfectly conducting body furrounded by the air, and what will be its action on another body. Thus we fhall obtain oftenfible refults, which we can compare with experiments. The writer of this article made many experiments with this view above 30 years ago, and flatters himfelf that he has not been unfuccefsful in his attempts. Thefe were conducted in the moft obvious and fimple manner, fuggefted by the reafonings of Mr Æpinus; and it was with fingular pleafure that, fome years after, he perufed the excellent differtation of Mr Cavendifh in the Philofophical Tranfactions, vol. 61. where he obtained a much fuller conviction of the truth of the conclufion which he had drawn, in a ruder way, from more familiar appearances. Mr Cavendifh has, with fingular fagacity and addrefs, employed his mathematical knowledge in a way that opened the road to a much farther and more fcientific profecution of the difcovery, if it can be called by that name. After this, Mr Coulomb, a diftinguifhed member of the French Academy of Sciences, engaged in the fame refearch in a way ftill more refined; and fupported his conclufions by fome of the moft valuable experiments that have been offered to the public. We fhall now give a very brief account of this argument: and have premifed thefe hiftorical remarks; becaufe the writer, although he had eftablifhed the general conclufion, and had read an account of his inveftigation in a public fociety in 1769, in which it was applied to the moft remarkable facts then known in electricity, has no claim to the more elaborate proofs of the fame doctrine, which is given in fome of the following paragraphs. Thefe are but an application of Mr Cavendifh's more cautious and general mathematical procedure, to the function which the writer apprehends to be fufficiently eftablifhed by obfervation.

Procefs for difcovering this law.

The moft unexceptionable experiments with which we can begin, feem to be the repulfions obfervable between

tween two *small* fpheres. Whatever be the law of diftribution of the particles in a fphere, the general action of its particles on the particles of another fphere will follow a law which will not differ much from the law of action between two particles, if the diameters of the fpheres be fmall in proportion to their diftance from each other. The inveftigation was therefore begun with them. But the fubject required an electrometer fufceptible of comparifon with others, and that could exhibit abfolute meafures. The one employed was made in the following manner; and we give it to the public as a valuable philofophical inftrument.

85 Comparable electrometer.

Fig 15. reprefents the electrometer in front. A is a polifhed brafs ball, ¼th of an inch in diameter. It is fixed on the point of a needle three inches long, as flender as can be had of that length. The other end of the needle paffes through a ball of amber or glafs, or other firm non-conducting fubftance, about half or three-fourths of an inch in diameter; but the end muft not reach quite to the furface, although the ball is completely perforated. From this ball rifes a flender glafs 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 ftalk DCB of the electrometer. This is formed by dipping a ftrong and dry filk thread, or fine cord in melted fealing-wax, and holding it perpendicular till it remain covered with a thin coating, and be fully penetrated by it. It muft be kept extended, that it may be very ftraight; and it muft be rendered fmooth, by holding it before a clear fire. This ftalk is faftened into a fmall cube of amber, perforated on purpofe, and having fine holes drilled in two of its oppofite fides. The cheeks of the piece C are wide enough to allow this cube to move freely between them, round two fine pins, which are thruft thro' the holes in the cheeks, and reach about half way to the ftalk. The lower part of the ftalk is about three inches long, and terminates in a gilt and burnifhed cork-ball (or made of thin metal), a quarter of an inch in diameter. The upper part CD is of the fame length, and paffes through (with fome friction) a fmall cork-ball. This part of the inftrument is fo proportioned, that when FE is perpendicular to the horizon, and DCB hangs freely, the balls B and A juft touch each other. Fig. 16. gives a fide perfpective view of the inftrument. The ball F is fixed on the end of the glafs rod FI, which paffes perpendicularly through the centre of a graduated circle GHO, and has a knob handle of boxwood on the farther end I. This glafs rod turns ftiffly, but fmoothly, in the head of the pillar HK, &c. and has an index NH, which turns round it. This index is fet 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 uppermoft, 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 ftiffly on the fame axis, and extending a good way beyond the circle.

This inftrument is ufed in the following manner: A connection is made with the body whofe electricity is to be examined, by fticking 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 infulated, 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 pofition, the line LA is horizontal, and fo is CB; and the moveable ball B is refting 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 fome particular pofition of the index, they will be obferved to feparate. Bring them together again, and again caufe them to feparate, till the exact pofition at feparation is afcertained. This will fhew their repulfive force in contact, or at the diftance of their centres, equal to the fum of their radii. Having determined this point, turn the inftrument ftill more toward the vertical pofition. The balls will now feparate more and more. Let an affiftant turn the long index fo as to make it parallel to the ftalk of the electrometer, by making the one hide the other from his view. The mathematical reader will fee that this electrometer has the properties afcribed to it. It will give abfolute meafures: for by poizing the ftalk, by laying fome 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 muft repel each other (when the ftalk is in a horizontal pofition), in order *merely to feparate*. Then a very fimple computation will tell us the grains of repulfion when they feparate in any oblique pofition of the ftalk; and another computation, by the refolution of forces, will fhew us the repulfion 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 reafon for giving the connection between A and C fuch 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 inftrument of more general ufe, and frequently to connect it with an electrical machine, a battery, or a large body, no mode of connection offered itfelf which would not have been more faulty in this refpect. The neateft and moft compendious form would have been to attach the axis FI to C, and to make CA and CB ftiff metalline wires, in the fame manner as Mr Brookes's electrometer is made. But as the whole of their lengths would have acted, this conftruction would have been very improper in the inveftigation of the law of electric repulfion. As it now ftands, we imagine that it has confiderable advantages over Mr Brookes's conftruction; and alfo over Mr De Luc's comparable electrometer, defcribed in his Effays on Meteorology. It has even advantages over Mr Coulomb's incomparably more delicate electrometer, which is fenfible, and *can meafure* repulfions which do not exceed the 50,000 of a grain; for the inftrument which we have defcribed will meafure the *attractions* of the oppofitely electrified bodies; a thing which Mr Coulomb could not do without a great circuit of experiments. For inftead of making the ball B *above* A, by inclining the inftrument to the right hand, we may incline it to the

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 $\frac{1}{8}$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.

86 Spheres, when electrified, repel with a force proportional to $\frac{1}{x^2}$;

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.

87 And attract according to the ſame law.

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.

88 Attractions and repulſions are equal at equal diſtances.

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.)

89 Electric action is inverſely as the ſquare of the diſtance.

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.

90 Diſpoſition of ſuch fluid when redundant or deficient.

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:

91 Lemma.

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

the whole matter or fluid in $a\,b\,d$. For the attraction for a particle in ABD is to the attraction for a particle similarly placed in $a\,b\,d$ as $P\,c^2$ to PC^2; and the number of particles in ABD is to that of those in $a\,b\,d$ as PC^2 to $P\,c^2$; therefore the whole attraction for ABD is to that for $a\,b\,d$ as $P\,c^2 \times PC^2$ to $PC^2 \times P\,c^2$, 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.

92 Disposition in parallel plates,

Let A $a\,d$ D (fig. 18.) and E $e\,h$ H 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.

When both are overcharged,

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, A $a\,b$ B and G $g\,h$ H, 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 C $c\,d$ D, containing the quantity $\frac{r-s}{2}$ crowded together.

3. The adjacent side of E will have a stratum E $e\,f$ F, 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 B $b\,c$ C and F $f\,g$ G will be in their natural state.

For a particle of fluid in the space B $b\,c$ C is urged in the direction $a\,d$ by the force $\frac{r+s}{2}$ (n° 91, 3.), and in the direction $d\,a$ by the force $\frac{r-s}{2}$, therefore it is, on the whole, urged in the direction $a\,d$ with the force s, which will balance the repulsion of the redundant fluid in the other plate. A particle of fluid in the space F $f\,g$ G is repelled in the direction $h\,e$ by a force $\frac{r+s}{2}$ by the fluid in G $g\,h$ H, and it is attracted in the same direction by the redundant matter in E $e\,f$ F, 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 A $a\,b$ B or C $c\,d$ D 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. 93.

94 When they are undercharged,

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 A a and H h 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 C $c\,d$ D will contain redundant fluid $\frac{s-r}{2}$, crowded close.

3. The stratum E $e\,f$ F will be deprived of fluid, and the quantity abstracted is $\frac{s-r}{2}$.

4. The spaces B $b\,c$ C and F $f\,g$ G are in the natural state.

The demonstration is the same as in the former case.

95 When they are in opposite states,

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 A $a\,b$ B and G $g\,h$ H contain the redundant fluid $\frac{r-s}{2}$, crowded close.

2. The stratum C $c\,d$ D contains the quantity $\frac{r+s}{2}$, crowded close.

3. The stratum E $e\,f$ F 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 C $c\,d$ D, and all the redundant matter being in E $e\,f$ F. 96.

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.

97 Pressure and tendency to escape.

When the two plates are overcharged, the fluid presses their remote surfaces with the force $\frac{\overline{r+s}^2}{4}$, 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 $\frac{\overline{r-s}^2}{4}$.

If one be overcharged and the other undercharged, fluid would escape from the remote surface with the force

force $\frac{\overline{r-s}^2}{4}$, and would run through a canal between them with the force $\frac{\overline{r+s}^2}{4}$.

Mutual actions. They repel or attract each other with the force $\overline{r+s}^2$ 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 *p q r* in which itſelf is ſituated, therefore not affected by what is between the ſurfaces ABD and *p q r*. He alſo demonſtrates, that the matter within the ſurface *p q r* 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 conſtipated 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 conſtipated 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 conſtipated 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 *a b d* 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 *a b d* will be entirely exhauſted of fluid, and there will be a ſhell $\alpha\beta\delta$ of redundant matter ſurrounding the ſphere. All within *a b d*, 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 conſtipated 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 conſtipated 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. 99 Conſequences of this diſpoſition.

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. 100 Verified by the phenomena. Electric Well explained.

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 electri-

fied.

fied. The experiment fucceeds as well with a metal globe; nay, even although the mouth be pretty wide; in which cafe, 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 fenfible electricity; but if we touch the outfide with the electrometer, it will inftantly be electrified and ftrongly repelled. Deep cylinders, and all round veffels with narrow mouths, exhibit the fame faintnefs of electricity within, except near the brims, although ftrongly electric without; and even open metal cups have the interior electricity much diminifhed.

101 Electric bodies are only fuperficially fo.

Reflecting on this valuable propofition of Mr Cavendifh, we fee clearly why an overcharged electric is only fuperficially fo; and that this will be the cafe even although we attempt to accumulate a great quantity of electricity in it, by melting it in a thin glafs globe, and electrifying it while liquid, and keeping up the accumulating force till it becomes quite cold. The prefent writer, not having confidered the fubject with that judicious accuracy that Mr Cavendifh exerted, had hopes of producing a powerful and permanent electric in this way, and was mortified and puzzled by the difappointment, till he faw his miftake on reading Mr Cavendifh's differtation.

Cautions in certain experiments.

Thefe obfervations alfo point out a thing which fhould be attended to in our experiments for difcovering the electricity excited in the fpontaneous operations of nature, as in chemical compofition and decompofition, congelation, fufion, evaporation, &c. It has been ufual to put the fubftances into glafs, or other nonconducting veffels, or into veffels which conduct very imperfectly. In this laft cafe efpecially, the very faint electricity which is produced, inftantly forms a compenfation to itfelf in the fubftance of the veffel, and the apparatus becomes almoft neutral, although there may have been a great deal of electricity excited. It will be proper to confider, whether the nature of the experiment will admit of metalline veffels. In the experiments on metalline folutions, the beft method feems to be, to make the veffel itfelf the fubftance that is to be diffolved.

102 Electricity more nearly proportional to the furface than to the quantity of matter.

For fimilar reafons we may collect, without a more minute examination, that bodies of all fhapes, when overcharged, will have the redundant fluid much denfer near the furface than in the interior parts; and denfer 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 furfaces 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 infulated metal difh furnifhed with an electrometer. Let one end be held an inch or two above the coil by a filk thread. Electrify the whole, and obferve 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 raife it.

103. We now fee with how little reafon Lord Mahon concluded that the point of his conductor, obferved to be neutral, correfponded with his theory; namely, one of the media of a harmonic divifion. We fee no reafon for beginning the computation at the extremity of the prime conductor. It certainly fhould not have been from the extremity. Had the prime conductor been a fingle globe, it fhould have begun from the centre of this globe. If it was of the ufual form, with an outftanding wire, terminated by a large ball, the action of the body of the conductor fhould certainly have been taken into the account. In fhort, almoft any point of the long conductor might have been accommodated to his Lordfhip's theory.

We might now proceed to inveftigate the diftribution 104.
of the electric fluid in bodies expofed to the action of others, and particularly in the oblong conductors made ufe of in our preparatory propofitions. The problem is determinate, when the length and diameter of cylindric conductors are given; but even when the electric employed for inducing the electricity is in the form of a globe, we muft employ functions of the diftances that are pretty complex, and oblige us to have recourfe to fecond fluxions. The mutual actions of two oblong conductors, of confiderable diameters, give a problem that will occupy the firft mathematicians; but which is quite improper for this fcanty abftract. Nor is a minute knowledge of the difpofition of the fluid of very important fervice. We may therefore content ourfelves with a general reprefentation of the ftate of the fluid in the following manner, which will give us a pretty diftinct notion how it will act in moft cafes:

General reprefentation of the difpofition of the fluid.

Let A (fig. 20.) be an overcharged fphere, and BC a conducting cylindric or prifmatic body; draw $b\,c$ parallel to BC, and erect perpendiculars B b, C c, P p, &c. to reprefent the equable denfity of the fluid, when the conductor is in its natural ftate; but let B d, C r, P s, &c. reprefent the unequal denfities in its different points, while in the vicinity of the overcharged fphere. Thefe ordinates muft be bounded by a line $d\,n\,r$, which will cut the line $b\,c$ 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 reprefented by the parallelogram BC $c\,b$; which muft therefore be equal to the fpace BC $r\,n\,d$: the redundant fluid in any portion CP or PN is reprefented by the fpaces $c\,r\,t\,p$, or $t\,p\,n$; and the redundant matter, or deficient fluid, in any portion BQ, is reprefented by $b\,d\,v\,q$. The action of this body on any body placed near it, depends entirely on the area contained between this curve line and its axis $b\,c$. The only circumftance that we can afcertain with refpect to this curve is, that *the variations of curvature* in every point are proportional to the forces exerted by the fphere A; and are therefore inverfely as the fquares of the diftances from A. This property will be demonftrated by and bye. The place of n, and the magnitude of the ordinates, will vary as the diameter of the conductor varies. We fhall confider this a little more particularly in fome cafes which will occur afterwards. We may confider the fimpleft cafe that can occur; namely, when the conductor is, like a wire, of no fenfible diameter, nay, as containing only one row of particles.

In a very flender canal the fluid muft be almoft equally diftributed.

Let AE (fig. 21.) be fuch a flender conducting canal; and let B b, C c, E e, &c. reprefent the denfity of the fluid which occupies it, being kept in this ftate of inequable denfity by the repulfion for fome overcharged body. A particle in C is impelled in the direction CE by all the fluid on the fide of A, and in the direction

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 $\beta c \varepsilon$ parallel to AE, this force of the element E will be expressed by $\frac{d\delta}{c\delta^2}\dot{x}$, 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 $\frac{f\varphi}{c\varphi^2}\dot{x}$, or $\frac{f\varphi}{c\delta^2}\dot{x}$, also impelling the particle in the direction CA. The joint action of these two elements therefore is $\frac{d\delta + f\varphi}{c\delta^2}\dot{x}$. If $b c e$ were a straight line, we should have $d\delta + f\varphi$ always proportional to $c\delta$; and it might be expressed by $m \times c\delta$; m being a number expressing what part of $c\delta$ the sum of $d\delta$ and $f\varphi$ 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, $d\delta$ does not increase so fast as $c\delta$, and $f\varphi$ increases faster than $c\delta$. However, in the immediate neighbourhood of any point C, we may express the accelerating force tending towards A by $\frac{mc\delta}{c\delta^2}\dot{x}$, without any sensible error; that is, by $m\frac{\dot{x}}{x}$; that is, by the fluxion of the area of a hyberbola HD′G, having CC′ and CK for its assymptotes; and the whole action of the fluid between F and D, on the particle C, will be expressed by the area C′GDD′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.

106
Communication and transference by canals.

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.

107
By crooked canals.

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.

Proposal for discovering redundancy of fluid.

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.

108
Action of a plate on a rectilineal canal.

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, 109
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 $\frac{f}{y^2}$. This,

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 $x : y = \dot{y} : \dot{x}$) $= f \times \frac{\dot{y}}{y^2}$. The variable part of the fluent is $= f\frac{-1}{y}$, and the complete fluent is $= f\left(C - \frac{1}{y}\right)$, 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 $f\left(\frac{1}{r} - \frac{1}{y}\right), = f\frac{y-r}{ry}$, expressing the action of a particle in the circumference of the plate on the fluid in the whole canal CP.

110 2. Required the action of the plate, whose diameter is A a, on the particle P?

1. On a single particle in the canal.

Let a represent the area of a circle, whose diameter is $= 1$. Then ar^2 is the area of the plate, and $2ar\dot{r}$ is the fluxion of this area: because $r : y = \dot{y} : \dot{r}$, $2ar\dot{r}$ is $= 2ay\dot{y}$. Therefore the fluxion of the action of the plate on the particle P is $f \times 2ay\dot{y} \times \frac{x}{y^3} = 2fa\,x \times \frac{\dot{y}}{y^2}$. The fluent of this has for its variable part $2fax \times \frac{-1}{y}$ (for when the particle P is given, x does not vary). This is $= 2fa \times \frac{-x}{y}$. 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 $2fa\left(1 - \frac{x}{y}\right)$.

111. 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° 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° 91—93.) Therefore, when x is very small in comparison of r, and consequently of y, $1 - \frac{x}{y}$ is very nearly $= 1$.

3. To find the action of the plate on the whole column? 112

2. On the whole canal.

The fluxion of this must be $= 2fa \times \left(1 - \frac{x}{y}\right)\dot{x}$, or $2fa\left(\dot{x} - \frac{x\dot{x}}{y}\right)$, or $2fa \times (\dot{x} - \dot{y})$; because $\dot{y} = \frac{x\dot{x}}{y}$. The fluent of this has for its variable part $2fa \times (x - y)$. 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 $= 2fa\,(x + r - y$.

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 $2fa \times$ 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. 113

Geometrical expression of these actions.

In like manner, by describing the arch Ai round the centre p, we have $2fa \times i$K for the action of the plate on the small column Cp; and $2fa \times$ Ii is the action of the plate on the portion Pp.

The general meaning of the expression $2fa \times$ 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. 114.

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 iK : 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. 115

Important corollary.

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 $fa\left(r - \frac{r^2}{y}\right)$. For the area of the plate is ar^2, and the 116

Action of a circumference on a canal.

the action of a particle in the circumference on the whole canal was ſhewn (n°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 Ap in B and b. Draw BD and bd parallel to PC. Then PB $= y - r$, and DC $= r\,\frac{y-r}{y}$. 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 Pp.

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 $2fa \times i$K to $1fa \times d$C, 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, conſtipated 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 $\frac{1}{\text{KC}} - \frac{1}{\text{KL}}$, 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 collected 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.

124 Action of a ſpherical ſurface, or ſhell, or ſolid, on the ſame canal.

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.

Let us now conſider the comparative actions of different plates or ſpheres on the canals.

125 Action of two plates, or two ſpheres, are as their diameters, when the canals are infinitely long.

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 $= 2a \times \overline{r + x - y}$, and when the column is infinitely extended, x is equal to y, and $\overline{r + x - y} = r$, 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.

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.

127 The proportion of the greateſt action is diminiſhed if the canals are ſhort.

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 $\frac{1}{10}$th of the radius, it will be $\frac{1}{10}$th of the radius of the ſmaller plate. Now $\frac{1}{10}$th of half the repulſion is equal to $\frac{1}{10}$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.

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 $CO \times \frac{1}{CO}$ to $co \times \frac{1}{co}$, or in the ratio of equality.

Actions of two spheres are equal if the density be inversely as the diameters;

129 *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 constipated 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.

Or if the quantity of redundant fluid be as the diameters.

130 *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 interjacent canal must be in equilibrio, and therefore equal. This will be the case only when the quantities of fluid are in the proportion of their diameters.

Two spheres overcharged in this proportion are in equilibrio if communicating by a very long canal.

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 equilibrio, 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.

Tendency of the fluid to escape is inversely as the diameter.

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 constipation, 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 attractions and repulsions), the escape *must* be desultory. It is actually so; 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 equilibrio 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 equilibrio 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 equilibrio by the intervention of the fluid in the canal, in perfect consistency with the laws of hydrostatical pressure.

This proposition agrees with hydrostatical laws.

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

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 indifferent whether the canal be straight or crooked.

The action of an overcharged sphere ACB (fig. 25.) on the fluid in the whole of a canal *d f* P 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 *h i* be a minute portion of the straight canal, and *f d* the portion of the crooked canal which is equidistant from the centre C of the sphere; draw the radii C*f*, C*d*, and the concentric arches *h f*, *i d*, cutting *f* C in *g*; and draw *g e* perpendicular to *f d*; the force acting on *i h*, impelling it toward P, may be represented by *h i*. The same force acting on *d f*, in the direction *c f*, must therefore be expressed by *g f*. This, when estimated in the direction of the canal *d f*, is reduced to *e f*; but it is exerted on each particle of *d f*. Now $df : gf = gf : ef$, and $df \times ef = gf^2, = gf \times hi$; therefore the whole force on *d f*, in the direction *d f*, is equal to the force on *i h*, in the direction *i h*. 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, 1*st*, 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. 2*d*, 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 1 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 $f \times \overline{n-1}$, and the action of DF on EN is mn; therefore, because the plate LM is inactive, the actions of AB and DF on EN must balance each other, and $f \times \overline{n-1} = mn$, and $m = f \times \frac{n-1}{n}$.

The

The repulsion of f for the fluid in CG is fn. The attraction of m for it is $m \times \overline{n-1}$; and because $m = f \times \frac{n-1}{n}$, the attraction of m for the fluid in CG is $f \times \frac{\overline{n-1}}{n} \times \overline{n-1}$. Therefore the repulsion of f is to the attraction of m as fn to $f \times \frac{\overline{n-1}^2}{n}$, or as fn^2 to $f \times \overline{n-1}^2$, or as n^2 to $\overline{n-1}^2$. Call the repulsion of f r, and the attraction of m a.

We have $r : a = n^2 : \overline{n-1}^2$

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 $n^2 : 2n - 1 = f : \text{F}$, and $\text{F} = f \frac{2n-1}{n^2}$, or $f = \text{F} \frac{n^2}{2n-1}$. 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° 115.) that $1 : n$ nearly $=$ CE : CA, or that n is nearly $\frac{\text{AC}}{\text{EC}}$. 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 $\text{F} \times \frac{n}{2}$ very nearly. Suppose CA to be six inches, and CE to be $\frac{1}{20}$th of an inch; this will give $n = 120$, and $f = 60$ F; or, more exactly, $\text{F} = \frac{n^2}{2n-1} = \frac{14{,}400}{239}$; $= 60\frac{1}{4}$. If, instead of the plate HK, we employ a globe of the same diameter, f will be but half of this quantity, or $f = \text{F} \times \frac{n}{4}$ (n° 123, 124.)

136 And evacuation: 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 $= f \times \overline{n-1}$.

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° 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.

138 Method of destroying this great accumulation: 1. By degrees; 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 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.

139 2. All at once. But this may be done in a much more expeditious way. Suppose a slender conducting canal $a\,b\,d$ 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 $a\,b$ 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 $a\,b\,d$, and to enter into DF at D.

140 The plates strongly attract each other. 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.

With this particular and remarkable case of induced electricity, we shall conclude our explanation of Mr Æpinus'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.

141 Method of examining the validity of this theory. These comparisons are abundantly supplied by the preceding paragraphs, particularly by n° 74, 75, 76; by n° 130, and by n° 134.

Let a smooth metal sphere be electrified positively in any manner whatever, and then touch it with a small one

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 electrometer. 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 $\frac{3}{2}$, $\frac{3}{4}$, $\frac{3}{8}$, &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, $\frac{1}{2}$, $\frac{1}{4}$, &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 $\frac{1}{2}$, $\frac{1}{4}$, &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 action is well determined. 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 ſatisfaction 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 ſerious 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 betwen the firſt experiments with charged glaſs by Kleiſt, 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, Wilcke, 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 to

146 Of the Leyden 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 pantheon 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° 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 glaſs completed 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° 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 $\frac{1}{20}$th of an inch of another equal plate which communicates with the ground; and it appears in n° 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. 149.

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 roſin, 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° 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, before 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.

152 State of the coatings.

While the plates AB and DF are near each other, eſpecially when DF communicates with the ground, if 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° 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 opake, 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. Inſtead

ſtead of being reduced to one half, it was more than two-thirds; and in the kind called Dutch plate, the diminution was inconſiderable.

154 Strong attraction between them.

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 electriſied, 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 $\frac{1}{12}$ 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.

155 Diſcharge; how it is effected.

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.

156 Beautiful and inſtructive experiment by Profeſſor Richmann.

The following obſervation of Profeſſor Richmann of St Peterſburgh (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.

Theory of it.

All theſe phenomena are not only conſequences of the theory, but their meaſures agree preciſely with the computations deduced from the formulæ in nº 22, 23, 24, accommodated to the caſe by means of nº 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 the

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 × $\frac{9}{10}$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 additional 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 157 Electric action *at a diſtance* demonſtrated.

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° 144.) We may therefore proceed with ſome confidence, and apply this doctrine even to caſes where experiment does not offer itſelf for proof.

158 Franklin miſtaken in ſuppoſing that a charged plate contains its natural quantity of fluid.

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 mth jar of the ſeries will therefore be $\overline{\frac{n-1}{n}}\Big|^{m}$. 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.

159 Miſtake of Wilcke's.

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 connected 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° 156. when d riſes no more.

160 Charge one jar by the diſcharge of another.

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 2² always remaining, whatever may have been the magnitude of n.

161 Important inference.

We may infer from this experiment, that when a ſhock is given to a number of perſons a, b, c, &c. we are not to conclude, that the fluid which comes into 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.

162 Leyden phial like a coated pane.

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.

163 Excellent method for verifying the theory.

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 how

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 $\overline{1+x}$ to 1. If m communications have been made, it will be reduced in the proportion of $\overline{1+x}^m$ to 1. Therefore $\overline{1+x}^m = 2$, 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 Cunæus. A continuous plating is preſcribed, in preference to ſome methods commonly practiſed; ſuch as filling the jar with braſs 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 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.

Hint for medical exhibition of electricity.

166

How to prevent the burſting of jars by high charges.

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 deſultory, 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

Very curious obſervation by Mr Cuthbertſon.

Mr Cuthbertſon, an excellent artiſt in all electrical apparatus, and inventor of the beſt air-pump, has made a 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 deſultory 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

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 poſſint.* 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 (*a b c d*), (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.

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. 170 Another.

We have made a very fine electric phial for carrying about, by forming tin-plate (iron plate tinned) into ſomewhat of a phial ſhape, with a long neck. We then covered this with a coating of fine ſealing wax, about $\frac{1}{10}$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. 171 Portable jar.

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 172 Importance of a cloſe diſcharge.

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 *a b* (fig. 32.) be discharged by a wire *a c d e b*, interrupted at *c d* 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 *x s* 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 *c d*, it will *probably* be positive in *c d*, and negative in *x s*; 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 *c d* 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 formulæ 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 tinfoil 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 electrics 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? 175 Does the charge reside in the coatings or in the glass?

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 176 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.

177 Charged glaſs acquires redundant and deficient ſtrata.

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. Tranſ. 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.

178. 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 $E \varepsilon \varphi F$. If we now ſuppoſe all the redundant fluid to be lodged in $b \beta \delta d$, and $e \varepsilon \varphi f$ 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 $b\,d$, will be nearly as much attracted by $\varepsilon e f \varphi$ 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 $\varepsilon e f \varphi$. (n° 42.) But the difference will be very ſmall indeed. (*N. B.* the reſult would be very different if electric action 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 electrics, 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 conſtipated ſtratum coming in contact with another. 179 Conjecture about the burſting of jars.

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 180 Several phenomena explained.

and

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° 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 attended 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.

184 The impermeability of electrics denied by ſome.

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° 176.

185 Bars touched like magnets for electricity.

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

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.

186 Electrophorus. 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° 14. to 25. and their companions in n° 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° 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,

Phenomena thereof. 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° 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. 187 Diſpoſition of the fluid

If the extent of the plates were incomparably greater than their thickneſs, we may infer from n° 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

188 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° 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° 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 AB*ba*A containing redundant matter, and a ſtratum *ab*CD containing redundant fluid: and the ſole has a ſtratum DC*nm* containing redundant fluid, namely, all that belongs naturally to the ſpace DCFE, and a ſtratum *mn*FE containing redundant matter. This may be called the PRIMITIVE STATE of the cake and ſole; and if once changed by communication with unelectrified bodies, it can never be recovered again without ſome new excitement.

189 *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 AB*ba* 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 G*gp*H, containing redundant matter, and another *gp*BA, containing redundant fluid. But this will diſturb the arrrangement 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 *gp*CA than it is attracted by the equivalent, but more remote redundant matter in GH*pg*. 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 GH*pg* and by AB*ba* 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 AB*ba* 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. 192 *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° 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 pafs from the cover to the cake. We do not *fully* underftand what prevents this communication, nor indeed what prevents the rapid efcape from an overcharged body into the air. This caufe, whatever it be, operates here; and the beft way of preventing the diffipation, or the abforption by the cake, is to keep the electrophorus with its cover on. It will come into this neutral ftate by diffipation from the fole, and abforption by the cover, in no very long time; and after this, will remain neutral, retaining its power with great obftinacy, efpecially if the cake and plates are very thin.

194 *Charging or active ftate.* VI. If the cover be now removed to a diftance, both parts of the apparatus will fhew ftrong marks of electricity. The cover contains much redundant fluid, and muft appear ftrongly pofitive, and will give a bright fpark, which may be employed for any purpofe. It may be employed for charging a jar pofitively by the knob, if we juft touch the cover with the knob. The fole will attract fluid, or be negative, although it contain more than its natural quantity of fluid, and it will take a fpark. The fole therefore, in the abfence 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 ftate defcribed in N° II.; and now all the former experiments may be repeated. We may call this the ACTIVE or the CHARGING ftate.

Electrophorus not a magazine of electricity, but a collecting machine. This ftate of the apparatus has caufed it to get the name *Electrophorus*. Volta, its undoubted inventor, called it *Electroforo perpetuo*; for it *appears*, as has been already obferved, to contain a magazine of electricity. The cover, when removed, will charge a jar held in the hand pofitively; and having done this fervice, it will charge a jar negatively when again fet on the cake. The fole, in the abfence of the cover, will charge a third jar negatively; and then, when the cover, after being touched, is fet down again, it will charge a fourth jar pofitively. It will not be difficult to contrive a fimple mechanifm, connected with the motion of the cover, which fhall connect the joined parts with two jars, and fhall connect them, when feperated, 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 furrounding bodies, which it afterwards imparts to others, and may be employed to difcharge jars in the fame gradual manner as to charge them.

195. VII. If the electrophorus is not infulated, a fhock may ftill be obtained, by firft touching the fole, and then, without removing the finger, touching the cover: but this will not be fo fmart as when the negative cover is touched at the fame time that we touch the fole, more highly pofitive than when it communicates with the ground. The difference muft, however, be almoft imperceptible when the pieces are thin.

196. VII. If the electrophorus is not infulated, the cover, when put on, will give a fpark in the manner already mentioned, and it will be fomewhat ftronger than when it is infulated; becaufe the fluid is allowed to efcape from the fole, and does not obftruct the entry into the cover. If we then, without removing the finger from the cover, touch the fole, nothing is felt; but if we firft touch the fole, and, without removing the finger from it, touch the cover, we obtain a fhock. This is evident from the theory. By this feries 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 feparated, the whole is reduced to the common ftate. When feparated, from being in the neutral ftate, they have oppofite electricities, the fole fhewing that of the cake When brought together, each in the common ftate, they have oppofite electricities, the cover fhewing that of the cake.

IX. When, by long expofure to the air without its cover, the electrophorus has loft its virtue, it may be brought again into an active ftate in a variety of ways. 197 How it may be recreated. Its furface may be rendered negative by friction with dry cat or hare fkin, or warm flannel. It may be rendered negative by fetting on it a jar charged negatively on the infide, and then touching the knob with any thing communicating with the ground. This is the moft expeditious method, and will give it a high degree of excitation, if the jar be of fize, and if the electrophorus be covered with a plate of tinfoil which comes into contact all over its furface. This however requires the previous charging of the jar; therefore it will be as expeditious and effectual to connect this furface with the rubber of an electrical machine. We had almoft forgotten to remark, that the effects of bringing the cover edgewife to the cake follow clearly from the theory, as will appear to the attentive reader without further explanation.

The electrophorus has been compared to a charged plate of coated glafs. 198 It is not fimilar to a charged pane. It is true that it *may be brought* into an external ftate which very much refembles a charged pane; namely, when the cover, in its natural ftate, is fet on the electrophorus in its natural ftate: and accordingly it gives a fhock, and the two exterior furfaces become neutral; but the internal conftitution, and the acting forces, are totally and *effentially* different. The two coatings of the pane would not, when feparated, exhibit the appearances of the electrophorus; nor, when touched in their disjoined ftate, will they produce the fame effects when joined. In the operation of coated glafs, the conftant or invariable part, the glafs is not the *agent*, it is merely the *occafion* of the action, by *allowing* the accumulation. In the electrophorus, the electric, which is the conftant invariable part, is the *agent producing* the accumulation. The electrophorus is an original, and a very ingenious and curious electrical machine. Nothing has fo much contributed to fpread fome general, though flight, acquaintance with the mechanical principles of electricity. The numerous dabblers in natural knowledge had been diverted from fcientific purfuit by the variety of the fingular and amufing effects of electricity, and had really attained very little connected knowledge. The effects of the electrophorus *forced* this knowledge on them; becaufe no ufe can be made of it without a pretty clear conception of the difpofition of the electricity, and the kind and intenfity of the actions. It is therefore moft ungrateful in the experimenters who have attained better views, to attempt to rob Mr Volta of the real merit of difcovery, by fhewing that its effects are fimilar to thofe of Mr Symmer's ftockings, or of Cigna's plates, or of Franklin's charged or difcharged glafs panes. And the at-

tempt

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.

199 *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 conſtipating 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. Theory thereof. 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 condenſator 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

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 hardeſt 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 inconveniency 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.

204 Diſſipation of electricity from ſharp points.

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.

To ſee this in its full force, the phenomenon itſelf 205.
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, the

the afflux of the air from behind is prevented, and we have no ftream; but if the cork be removed, and the wire ftill occupy the axis of the tube, but without touching the fides, we have the ftream very diftinctly; and fmoke which rifes round the far end of the tube is drawn into it, and goes of at the point of the wire. Now it is of importance to obferve, that whatever prevents the formation of this ftream of wind prevents the diffipation of electricity (for we fhall not fay efcape 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 ftream is ftrong, and the diffipation fo rapid, that even a very good machine is not able to raife a Henly's electrometer, ftanding on the conductor, a very few degrees. If the tube be flipped forward, fo that the point is juft even with its mouth, the diffipation of electricity is next to nothing, and does not exceed what might be produced by fuch air as can be collected by a fuperficial point. If the tube be made to advance half an inch beyond the point which it furrounds, the diffipation becomes infenfible. All thefe facts put it beyond a doubt that the air is the caufe, or, at leaft, the occafion of the diffipation, 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 fharp electrified point is electrified and thrown off.

Theory of it.

It was demonftrated in n° 130, that two fpheres, connected by an infinitely extended, but flender conducting canal, are in electrical equilibrium, if their furfaces contain fluid in the proportion of their diameters. In this cafe, the fuperficial denfity of the fluid and its tendency to efcape are inverfely as the diameters (n° 130). Now if, in imagination, we gradually diminifh the diameter of one of the fpheres, the tendency to efcape will increafe 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 fucceffive burfts from this ball. Being much more overcharged than any other part of the body, the air furrounding the ball becomes more overcharged by communication, and is repelled, and its place fupplied by other air, not fo much overcharged, which furrounded the other parts of the body, and is preffed forwards into this fpace by the general repulfion of the conductor and the confining preffure of the atmofphere; otherwife, being alfo overcharged, it would have no tendency to come to this place. Half a turn of the cylinder is fufficient to accumulate to a degree fufficient for producing one of thefe explofions, and we have two of them for every turn of the cylinder, A point may be compared to an incomparably fmaller ball. The conftipation of the fluid, and its tendency to efcape, muft be greater in the fame unmeafurable proportion. This denfity and mutual repulfion cannot be diminifhed, and muft even be increafed, by the matter of the wire forming a cone of which the point is the apex; therefore, if there were no other caufe, we muft fee that it is almoft impoffible to confine a collection of particles, mutually repelling, and conftipated, as thefe are in a fine point.

But the chief caufe feems to be a certain chemical union which takes place between the electric fluid and a correfponding ingredient of the air. In this ftate of conftipation, almoft completely furrounded by the air, the little mafs of fluid muft attract and be attracted with very great force, and more readily overcome the force which keeps the electrified fluid attached to the laft feries of particles of the wire. It unites with the air, rendering it electric in the higheft degree of redundancy. It is therefore ftrongly repelled by the mafs of conftipated fluid which fucceeds it within the point. Thus is the electrified air continually thrown off, in a ftate of electrification, that muft rapidly diminifh the electricity of the conductor. Hence the uninterrupted flow, without noife or much light, when the point is made very fine. When the point is blunt, a little accumulation is neceffary before it attains the degree neceffary for even this minute explofion; but this is foon done, and thefe little explofions fucceed each other rapidly, accompanied by a fputtering noife, and trains of bright fparks. The noife is undoubtedly owing to the atoms of the highly electrified fluid. Thefe are, in all probability, rarefied of a fudden, in the act of electrification, and immediately collapfe again in the act of chemical union, which caufes a fonorous agitation of the air. This electrified air is thus thrown off, and its place is immediately fupplied by air from behind, not yet electrified, and therefore ftrongly drawn forward to the point, from which they are thrown off in their turn. This rapid expanfion and fubfequent collapfing of the air is verified by the experiments of Mr Kinnerfly, related by Dr Franklin, and is feen in numberlefs 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 fame kind with what occafions the burfting of ftones, fplitting of trees, exploding of metals, &c. by electricity. The expanfion is either inconfiderable, or it is fucceffively produced in very fmall portions of the fubftance expanded; for when metal is exploded in clofe veffels, or under water, there is but a minute portion of gazeous matter produced, and in the diffipation by a very fine point, fufficiently great to give full employment to a powerful machine, the ftream 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.

206 Electricity unites chemically with air.

From a collation of all the appearances of electricity, we muft form the fame conception of the forces which operate round a point that is negatively electrified, not difperfing, but drawing in electric fluid. It is more completely undercharged than any other part of a body, and attracts the fluid in the furrounding 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 ftream like the overcharged point.

If a conducting body be brought near to any part of an overcharged body, the fronting part of the firft is rendered undercharged; and this increafes the charge of the oppofite part of the overcharged body. It becomes more overcharged in that part, and fooner attains that degree of conftipation that enables the fluid to quit the fuperficial feries of particles, and to electrify ftrongly the contiguous air. The explofion is therefore made in this part in preference to any other; and the 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 *quaqua 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.

209 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 beyond contact, that to extricate their effects from the complicated phenomenon ſeems a deſperate problem.

Characteriſtic differences of poſitive and negative electricity.

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 emerſion 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, curvilineal, 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 mechanician 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; P*ab*N lies within the other, and arrives in a direction nearly perpendicular to the axis; PαBN 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.

210 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 *Gottingen Commentaries*; to the *Publication of the Haarlem Society*; to the *Gotha Magazine*; to *Dissertations by Spath* at Altdorff, and other German writers.

211 Dissipation of electricity into the air is proportional to the density.

It only remains for us to take notice of the general laws of the dissipation 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 dissipation of moderate degrees of electricity is proportional to the degree of electricity at the moment. He found that the dissipation 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 dissipation 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 dissipation of electricity:

Hygrometer.	Grains water in cubic foot.	Dissipation per minute.
69	6,197	$\frac{1}{60}$
75	7,295	$\frac{1}{41}$
80	8,045	$\frac{1}{29}$
87	9,221	$\frac{1}{14}$

Hence it follows, that the dissipation is very nearly in the triplicate ratio of the moisture of the air. Thus if

$$\frac{60}{41} \text{ be considered as } = \left(\frac{7,197}{6,180}\right)^m \text{ we have } m = 2,764$$

$$\frac{60}{29} \; . \; . \; . \; . \; . \; = \left(\frac{8,045}{6,180}\right)^m \text{ gives } m = 2,76$$

$$\frac{60}{14} \; . \; . \; . \; . \; . \; = \left(\frac{9,220}{6,180}\right)^m \text{ gives } m = 3,61$$

Hence, at a medium, $m = 3,40$.

We should have observed, that the ingenious author took care to separate this dissipation by immediate contact with the air, from what was occasioned by the imperfect insulation afforded by the supports.

213 Diminution of repulsion is double of the dissipation.

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 dissipation 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 dissipation, 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 dissipated bears to the whole quantity at the moment. For example, if we observe the repulsion diminished $\frac{1}{40}$, we conclude that $\frac{1}{80}$ of the fluid has escaped.

214. Mr Coulomb has not examined the proportion between the dissipations 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.

215 Dissipation depends on the state of the air.

It must be kept in mind, that the law of dissipation 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 dissipation shall be the same. The air is such a hetea 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.

216 Diſſipation by imperfect inſulators.

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.

Procedure thereof.

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 nº 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.

217 Theory thereof.

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, P*d*, &c. of ſome curve line D*d*B, which cuts the axis in B where the thread begins to inſulate completely. Let P*p* be an element of the axis. Draw the ordinate *pf*, the tangent *df*F, and the normal *d*E, and *fe* perpendicular to P*d*. Let AC be $= r$, AP $= x$, P*d* $= y$. Then P*p* $= \dot{x}$, and $de = -\dot{y}$. We have ſeen that the only ſenſible action on the particle of fluid in P is $-\frac{\dot{y}y}{\dot{x}}$ (ſee nº 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 $\frac{\dot{y}y}{\dot{x}} =$ 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 P*p*, 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 D*d*B 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 $Pd^2 : AD^2 = BP : BA$. 218 Variation of denſity in the inſulator.

2. The length of canal required for inſulating different denſities of electricity are as the ſquares of the denſities. For AB $= \frac{AD^2}{2\,PE}$; and PE has been ſhewn to be a conſtant quantity. Indeed we ſee in the demonſtration, that BP would inſulate a ball, whoſe electric denſity is P*d*, and BA : BP $= AD^2 : Pd^2$. 219 Length neceſſary for inſulation $\div$ denſity 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 $= \frac{DA^2}{2\,PE} = \frac{D^2}{2\,R}$. 220 Alſo $\div \frac{1}{\text{coercion}}$.

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.* $\frac{\dot{d}d}{\dot{x}}$ 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. Explanation of the efficacy of Volta's *condenſer*.

When

221. 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 equilibrio with the *maximum* of the coercive force of the inſulating interval. But it muſt be farther noticed, that this reſiſtance is not *active*, but coercitive, and we may compare it to friction or viſcidity. 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 $\frac{d\dot{d}}{\dot{x}}$ 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 $\frac{d\dot{d}}{\dot{x}}$ 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 $\dot{x}$ larger, that $\frac{d\dot{d}}{\dot{x}}$ 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 equilibrio with the maximum of reſiſtance. This conſideration will be applied to a valuable purpoſe in the article Magnetism.

222 Explanation of a curious and important fact; and method of increaſing a charge.

This doctrine gives, in our opinion, a very ſatisfactory explanation of the curious obſervations of Mr Brookes and Mr Cuthbertſon, mentioned in nº 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 D i a. This may be changed by damping, or properly dirtying (to uſe Mr Brookes's phraſe), to D f B; 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.

223 Cautions in deducing meaſures from experiments.

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.

224 Inſulating powers of various ſubſtances.

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 be 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 electrics than glaſs.

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.

The theory of Æpinus is only a hypotheſis.

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 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.

225 The reality of an electric fluid is denied.

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.

Requiſites for a juſt theory.

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.

226 No advantage is gained by the hypotheſis of two fluids.

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

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.

227 Hypothesis of Professor Russel.

The most specious of any that we know was publicly read in the university of Edinburgh by the late Mr James Russel, 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 Russel 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 Russel 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 Russel calls *elective 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 Russel 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 Russel'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.

228 Hypothesis of Mr de Luc.

Several years after the death of the Scotch Professor in 1773, a theory very much resembling this acquired great authority, being proposed to the philosophers by the celebrated naturalist 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 chances 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:

229. 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 deferent 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 electrical phenomena are affirmed to be *.

* See *Idées sur la Meteorologie*, § 266. &c.

1. As watery vapour or steam is composed of fire, the deferent fluid, and water, the gravitating part, so *electric fluid* is composed of the *electric deferent fluid*, and *electric matter.*

2. As *vapours* are partly decomposed when too dense for their temperature, and then their *deferent fluid* becomes free, and shews itself as *fire*; so *electric fluid* that is too dense is decomposed, and its *deferent 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 deferent* 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 deferent*, 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 deferent* 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 deferent* among neighbouring bodies, those which have proportionally most *electric matter* also retain most *deferent 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 deferent* 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 Russel, 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 *deferent 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 *deferent fluid.*

Hence the operation of *conductors* and *non-conductors;* and there is no other foundation for the notion of *idio-electrics* and *non-electrics*, 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 *deferent 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 *deferent 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 *deferent 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 theory 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. 231.

"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 *deferent 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 subserviency 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 philosophising 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 Russel 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° 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 Æpinian 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 ſlided 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 nº 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, deferent 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 corpuſcles would act, which repel each other with a force inverſely proportional to their diſtances; this action not extending beyond the adjoining corpuſcle, 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 into 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 Neutonien*, 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 rectilineal 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?* 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 Ruſſel'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 233.
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

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 $\frac{1}{10}$th, others $\frac{2}{10}$ths, others $\frac{3}{10}$ths, &c. in depth. *c* represents the edge of a small circle of gilt paper, $\frac{1}{4}$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 $\frac{1}{6000}$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*BF (fig. 38.) be a perfectly conducting body of any shape, and let *dae* be a thin slice separated from the rest by the plane *de;* let *dce* be precisely equal and similar to *dae*, and let *abc* be perpendicular to the separating plane; then the action of all the particles in the thin slice *dae* (when estimated in the direction *ab*) 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 *ab* sufficiently small, the difference of density at *a* and at *c* may be infinitely small; therefore the action of the fluid in *dae* will be infinitely near to an equilibrium with the action of *dce;* 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 constipated 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 $\frac{1}{2}$, $\frac{1}{3}$, $\frac{2}{3}$, &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

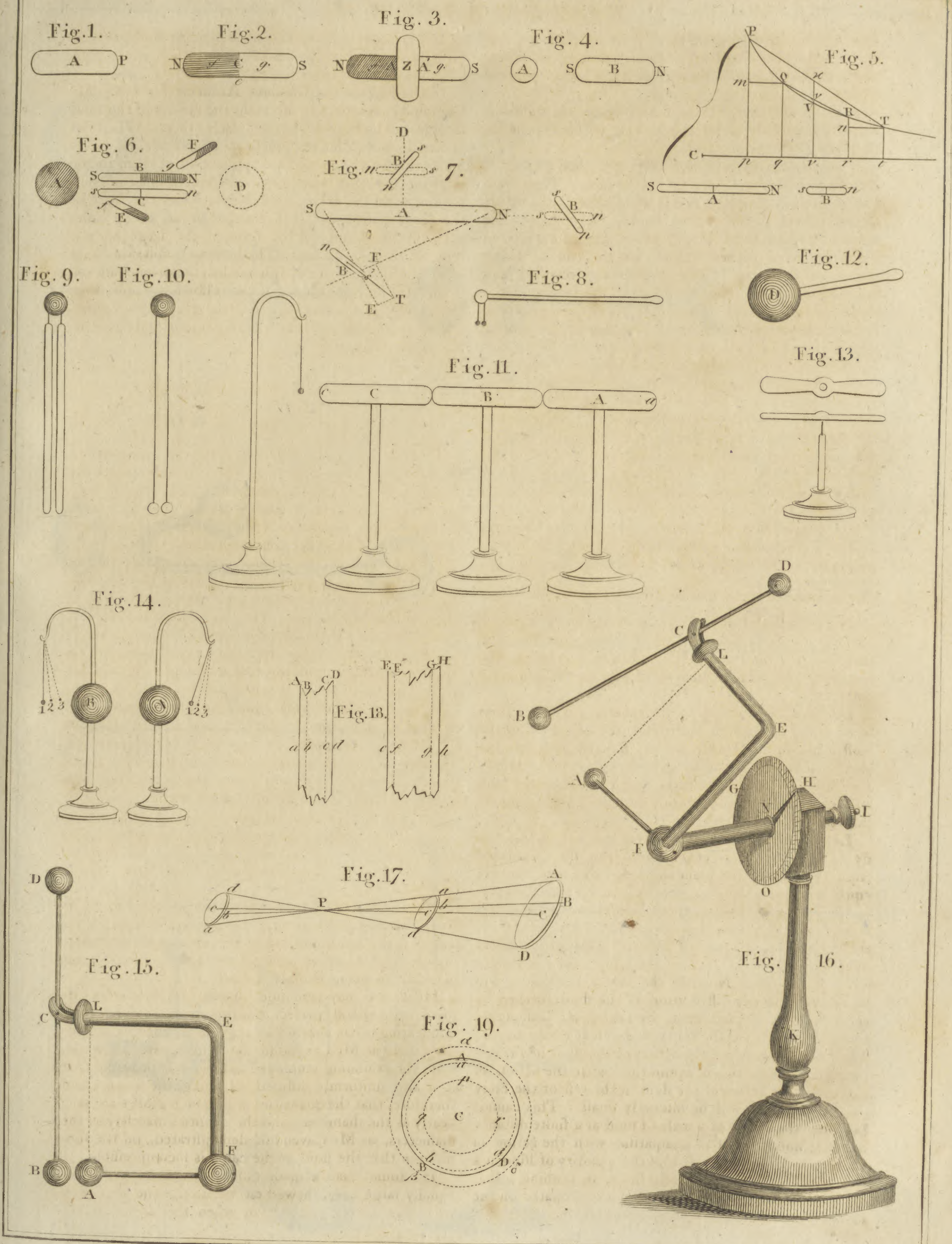


Fig. 1.
Fig. 2.
Fig. 3.
Fig. 4.
Fig. 5.
Fig. 6.
Fig. 7.
Fig. 8.
Fig. 9.
Fig. 10.
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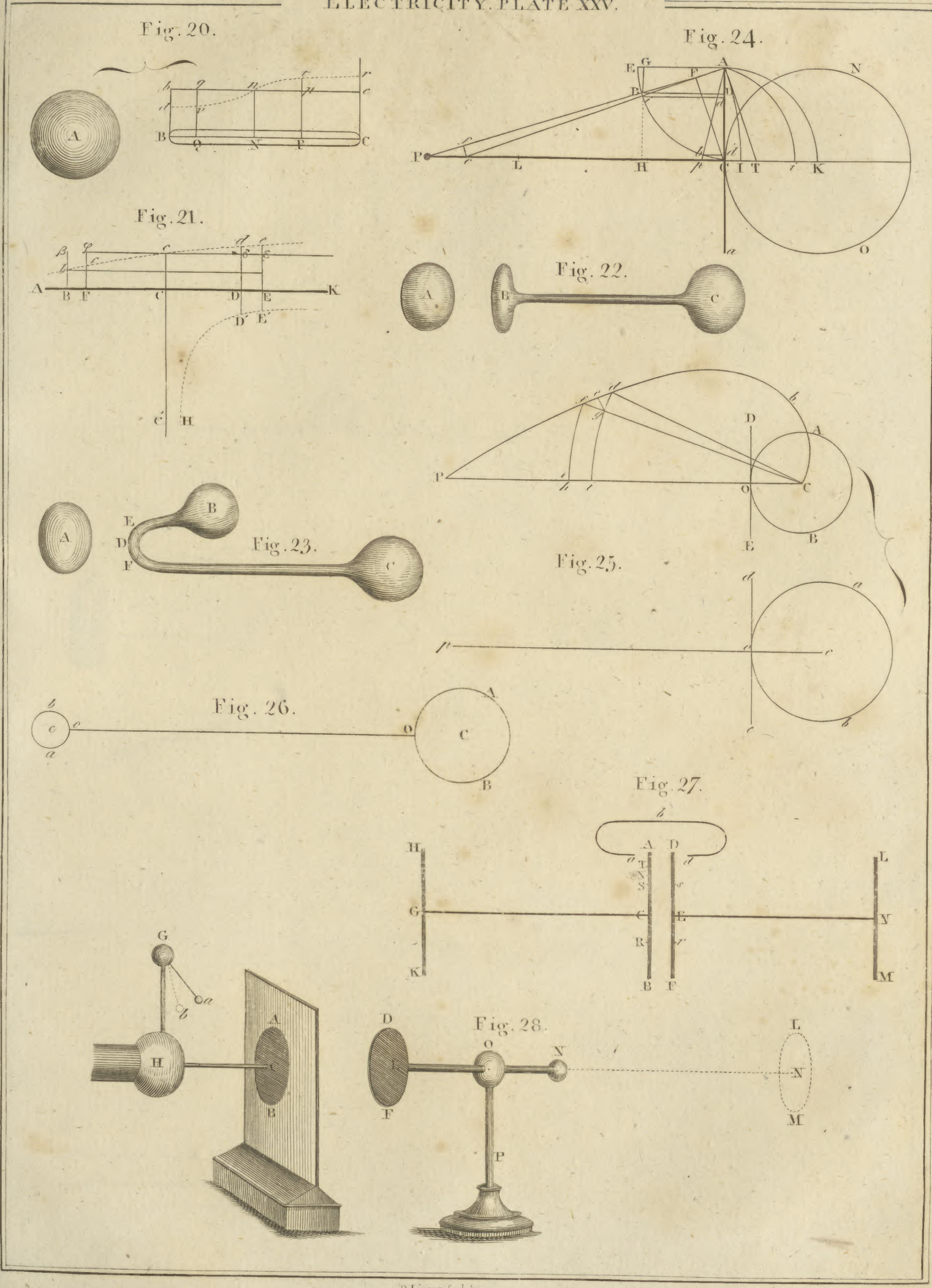
Fig. 19.



D Lizars sculp.

Fig. 29.

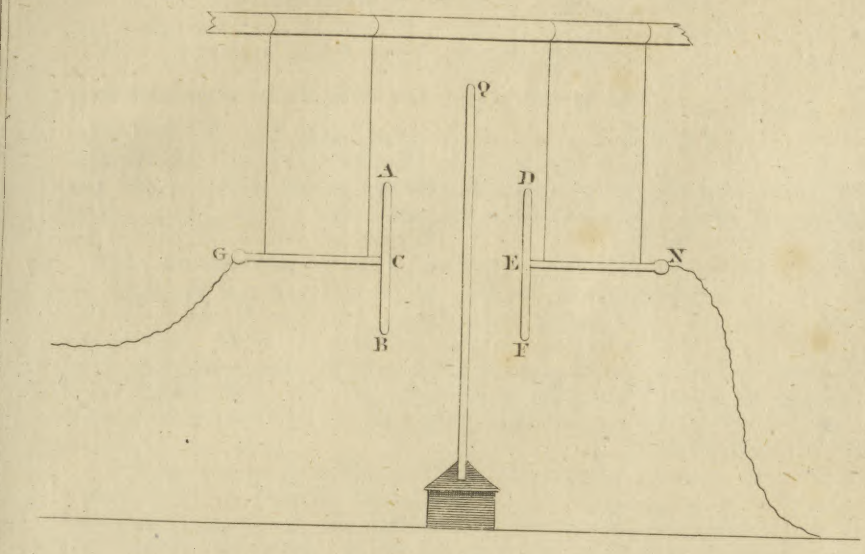


Fig. 30.

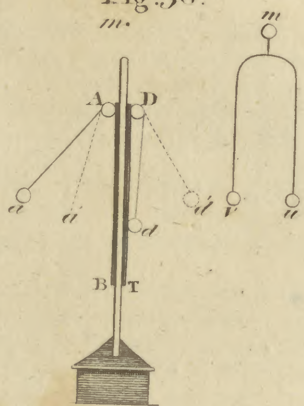


Fig. 31.

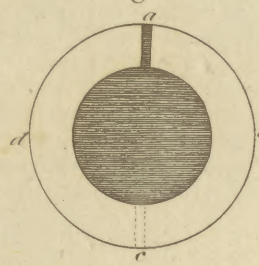


Fig. 32.

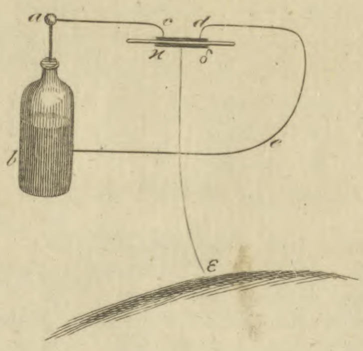
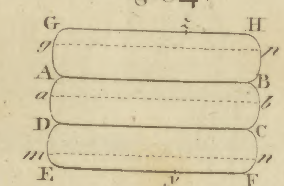


Fig. 34.



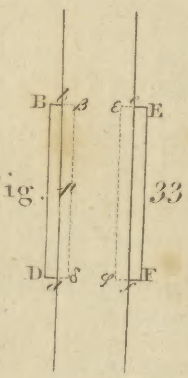
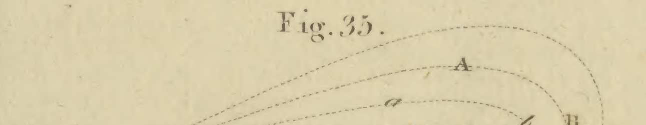


Fig. 35.



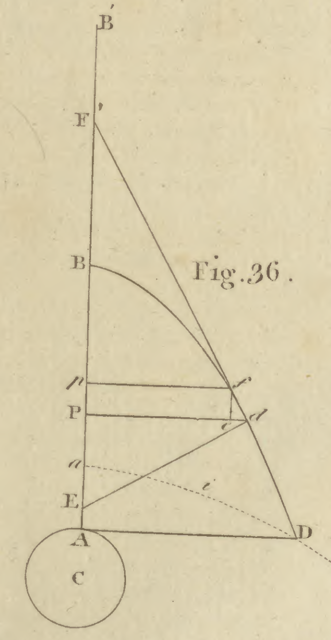


Fig. 37.

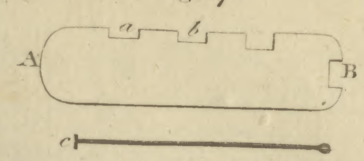
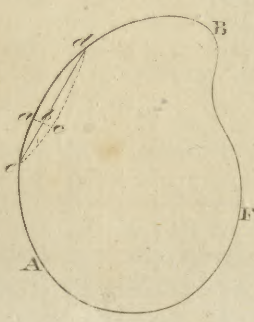


Fig. 38.



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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 $\frac{1}{2}$.

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.

Electricity, Electrometer.

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 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:

Electrometer.

ABDC (fig. 1.) repreſents a glaſs cylinder, 12 inches in diameter and in height. This is covered by 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 *f h*, 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 *e* (fig. 2. n° 2.), to which is joined the circular plate *a b*, 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

Plate XXVII.

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 *q*, formed like the end of a port-crayon, and tightened by the ring *q*, 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 *φ*. The lower end *φ 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 *q* 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 *q*: 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 pith 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 φ*, 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* OQ, and at the same time touches the ball *t* or *d*.

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° 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 $\frac{10}{145}$. Observe also, that the primitive force corresponding to the distance was 40; and the force corresponding to 20 was 160, or inversely as 20^2 to 40^2.

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 $\frac{1}{340}$th of a French grain, applied at the point *a*, held it fast till

till the twist-index was turned 360°; so that one degree corresponded to $\frac{1}{121400}$ of a grain. A foot of this wire weighed $\frac{1}{16}$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 *a g* being 2$\frac{1}{2}$ 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 *o* 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.*), n° 85. which was much more costly, and liable to accidents. Coulomb's electrometer has the great advantage of wasting very little electricity; whereas Henly'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 *c d*, 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. Trans.* 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 diamater, 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

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 Corſe, Eſq. They relate, 1*ſt*, 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 Corſe inſiſts 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 Corſe conceives cannot be leſs than two years; whereas Buffon 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 fœtus 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 Corſe 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.

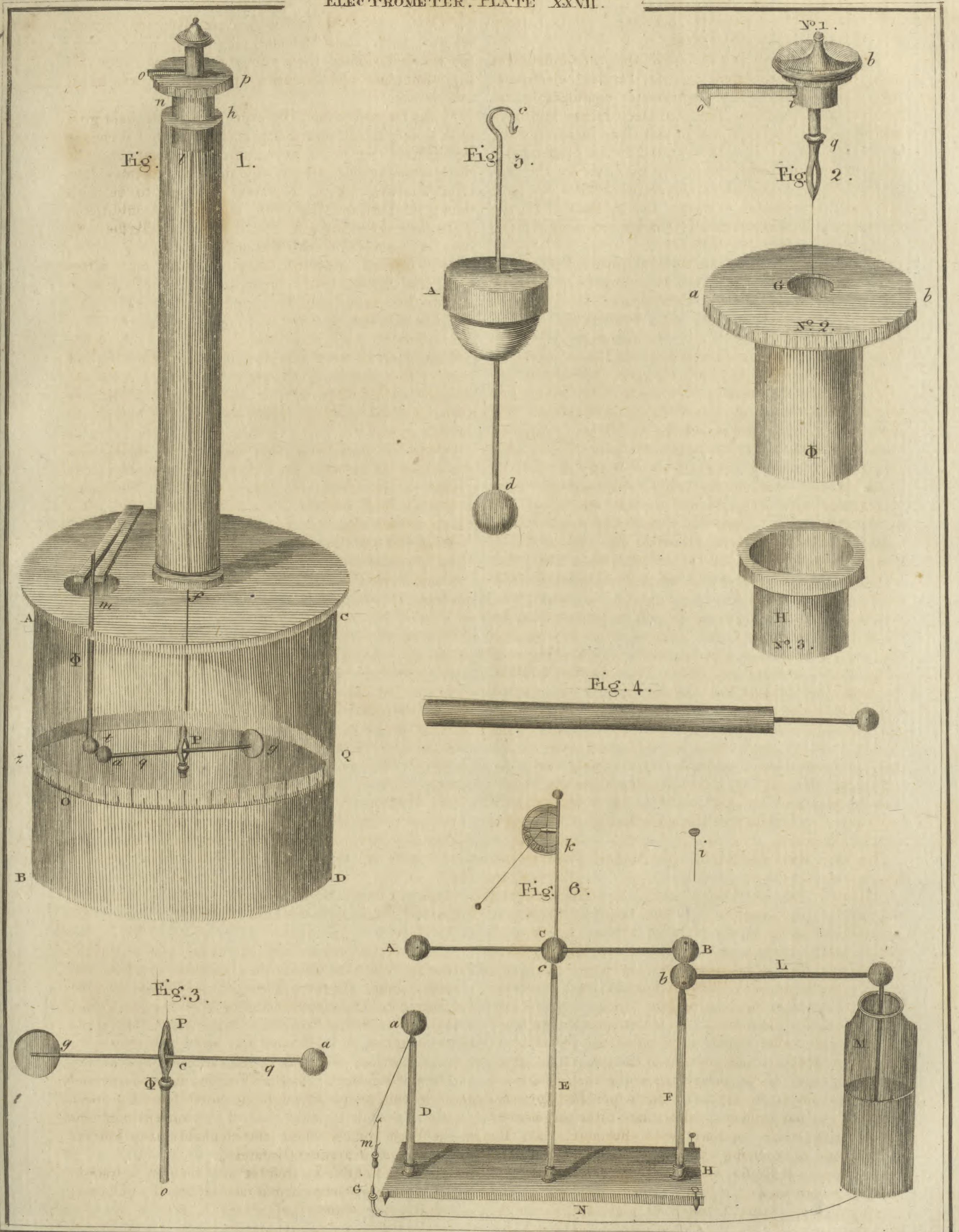
ELEPHANTIASIS (ſee Medicine, n° 352. *Encycl.*) is one of the moſt dreadful maladies with which the human race is anywhere afflicted. It is not indeed common, if it be found at all, in the temperate climates of Europe; but it is frequent in the Eaſt and Weſt Indies, where it too often baffles the ſkill 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 tólá, 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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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 $ay^{m+n} = bx^m.\overline{a-x}^n$ 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 elliptoides, denominated from the exponent $m + n$ of the ordinate y. As the cubical elliptoide, expressed by $ay^3 = bx^2.\overline{a-x}$; the biquadratic, or sursolid $ay^4 = bx^2.\overline{a-x}^2$; &c.

EMINENTIAL EQUATION, a term used by some algebraists, in the investigation of the areas of curvilineal 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 appearence, 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, carefully 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-solder 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° 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-

cy.

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 flour 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^os 1, 2, and 5; but they are also those which require the greatest heat. On the other hand, n° 9. may be recommended as

(A) This substance is itself a mixture, being composed of four parts of lead and one of tin.

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° 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° 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.

Enfield.

Mr Hextall, the diffenting minifter of that place, who took great care of his education, and infufed into his young mind that tafte for elegance in compofition which ever afterwards diftinguifhed him.

In his 17th year he was fent to the academy at Daventry, then under the direction of the Rev. Dr Afhworth, where he paffed through the ufual courfe of inftruction preparatory to the office of the miniftry; and with fuch fuccefs did he cultivate the talents of a preacher, and of an amiable man in fociety, that, on leaving the academy, he was at once chofen, in 1763, minifter of the very refpectable congregation of Benn's Garden in Liverpool.

In that agreeable town he paffed feven of the happieft years of his life, very generally beloved and efteemed. He married, in 1767, the daughter of Mr Holland draper in Liverpool, with whom he paffed all the reft of his days in moft cordial union. His literary reputation was extended, during his refidence in this place, by the publication of two volumes of fermons, which were very well received, and have ferved to grace many pulpits befides that in which they were originally preached. A collection of hymns and of family prayers, which he alfo publifhed at Liverpool, did credit to his tafte and judgment.

About 1770, he was invited to take a fhare in the conduct of the academy at Warrington, and alfo to occupy the place of minifter to the diffenting congregation there, both vacant by the death of the Rev. Mr Seddon. His acceptance of this honourable invitation was a fource of variety of mixed fenfations and events to him, of which anxiety and vexation compofed too large a fhare for his happinefs. No affiduity on his part was wanting in the performance of his various duties; but the difeafes of the inftitution were radical and incurable; and perhaps his gentlenefs of temper was ill adapted to contend with the difficulties, in matter of difcipline, which feem entailed on all diffenting academies, and which, in that fituation, fell upon him, as the domeftic refident, with peculiar weight. He always, however, poffeffed the refpect and affection of the beft difpofed of the ftudents; and there was no reafon to fuppofe that any other perfon, in his place, could have prevented that diffolution which the academy underwent in 1783.

During the period of his engagement there, his indefatigable induftry was exerted in the compofition of a number of works, moftly, indeed, of the clafs of ufeful compilations, but containing valuable difplays of his powers of thinking and writing. The moft confiderable was his "Inftitutes of Natural Philofophy" (quarto, Johnfon, 1783); a clear and well-arranged compendium of the leading principles, theoretical and experimental, of the fciences comprifed under that head. And it may be mentioned, as an extraordinary proof of his diligence and power of comprehenfion, that, on a vacancy in the mathematical department of the academy, which the ftate of the inftitution rendered it impoffible to fupply by a new tutor, he prepared himfelf, at a fhort warning, to fill it up; and did fill it with credit and utility, though this abftrufe branch of fcience had never before been a particular object of his ftudy. 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 diffenting congregation at Norwich, he accepted it, and firft fixed his refidence at Thorpe, a pleafant village near the city, where he purfued his plan of taking a limited number of pupils to board in his houfe. He afterwards removed to Norwich itfelf; and, at length, fatigued with the long cares of education, entirely ceafed to receive boarders, and only gave private inftructions to two or three felect pupils a few hours in the morning. This too he at laft difcontinued, and devoted himfelf folely to the duties of his congregation, and the retired and independent occupations of literature. Yet, in a private way and fmall circle, few men had been more fuccefsful in education, of which many ftriking examples might be mentioned, and none more fo than the members of his own family. Never, indeed, was a father more defervedly happy in his children; but the eldeft, whom he had trained with uncommon care, and who had already, when juft of age, advanced in his profeffional career fo far as to be chofen town-clerk of Nottingham, was moft unfortunately fnatched away by a fever a few years fince.

This fatal event produced effects on the doctor's health which alarmed his friends. The fymptoms were thofe of *angina pectoris*, and they continued till the ufual ferenity of his mind was reftored by time and employment. Some of the laft years of his life were the moft comfortable: employed only in occupations which were agreeable to him, and which left him mafter of his own time; witneffing the happy fettlement of two of his daughters; contracted in his living within the domeftic privacy which he loved; and connected with fome of the moft agreeable literary companions, and with a fet of the moft cordial and kind-hearted friends that perhaps this ifland affords, he feemed fully to enjoy life as it flowed, and indulged himfelf in pleafing profpects for futurity. Alas! an unfufpected and incurable difeafe was preparing a fad and fudden change: a fchirrous contraction of the rectum, the fymptoms of which were miftaken by himfelf for a common laxity of the bowels, brought on a total ftoppage, which, after a week's ftruggle, ended in death. Its gradual approach gave him an opportunity to difplay all the tendernefs, and more than the ufual firmnefs of his nature. He died November 3. 1797, amidft the kind offices of mourning friends, and his laft hours were peace!

Befides the literary performances already mentioned, Dr Enfield completed, in 1791, the laborious tafk of an abridgment of "Brucker's Hiftory of Philofophy," which he comprifed in two volumes quarto. It may be truly faid, that the tenets of philofophy and the lives of its profeffors were never before difplayed in fo pleafing a form, and with fuch clearnefs and elegance of language. Indeed it was his peculiar excellence to arrange and exprefs other mens ideas to the utmoft advantage. Perhaps, at the time of his deceafe, there was not in England a more perfect mafter of what is called the middle ftyle in writing, combining the qualities of eafe, elegance, perfpicuity, and correctnefs, entirely free from affectation and fingularity, and fitted for any fubject. If his caft of thought was not original, yet it was free, enlarged, and manly. What he was in the capacity of a teacher of religion, his feveral congregations will teftify with grateful and affectionate remembrance. Few minifters have paid fuch unremitting attention to the perfection of their pulpit compofitions;

Enfield || Engrafting.

fitions; nor was it only by detached difcourfes that he inculcated the truths of morality and religion, but by methodical plans of inftruction, drawn up with great care and comprehenfion. The valuable ftores of this kind which he left behind him will not be configned 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 impreffive, depending rather on the weight of juft enunciation than on the arts of oratory. Little need be added to this fketch of the moral qualities of the excellent man above commemorated. If moderation, compliancy, and gentlenefs were ever prevalent in him to a degree of excefs, who that knew him will blame an excefs which opened his foul to every emotion and office of affection and friendfhip?

This account of Dr Enfield, which is taken from the *Monthly Magazine*, is acknowledged by its author to be the effufion of friendfhip; but we believe that the panegyric, though high, is in general juft. It is our duty, however, to warn our readers againft placing implicit confidence in the Doctor's reprefentation of ancient philofophy; for though we have frequently found him correct, and have therefore quoted him with approbation ourfelves, we have likewife found him fometimes miftaking the fenfe of his authors. In a work like his, miftakes were indeed unavoidable; for when he refolved to comprefs the fubftance of Brucker's five volumes within the compafs of two, he could not avoid fometimes giving what he thought the *fenfe* of the ancients, when accuracy required their very *words* to be given. This we believe to be the fource of thofe errors in his elegant hiftory, which we have heard others unjuftly attribute to defign; for had it been his *defign* to deceive, he would not furely have ftored his margin with references to enable every reader to detect the deceit.

ENGINEER, is the appellation of him whofe profeffion it is to contrive or make any kind of ufeful engine or machine. He is denominated either a civil or military engineer, according as the objects of his profeffion refpect civil or military purpofes. See FORTIFICATION, *Encycl.* and MACHINE in this *Supplement*.

ENGONASIS, in aftronomy, the fame as Hercules, one of the northern conftellations.

ENGRAFTING. See GRAFTING, *Encycl.* where it is faid that there is little hope of producing mixed fruits by engrafting one tree upon another of the fame clafs. We confefs ourfelves to be unwilling to relinquifh this opinion; but it would be very unfair to withhold from the public any fact which feems to militate againft it, and has come to our knowledge. We fhall therefore tranfcribe from the *Philofophical Magazine* the following communication from Dr Thornton, lecturer on medical botany at Guy's Hofpital, refpecting a fuppofed *lufus naturæ*, which he confiders as the confequence of engrafting.

In the firft volume of the *Philofophical Tranfactions*, N° 29. publifhed 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 fame Tree."

Enneadecateris || Scotch Epifcopalians.

We have here orange trees (faith the intelligence from Florence) that bear a fruit which is citron on one fide 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 (fays the editor of the Tranfactions of the Royal Society) by a very ingenious Englifh gentleman, who afferted, that himfelf not only had feen, but bought of them, anno 1660, in Paris, whither they had been fent by Genoa merchants; and that on fome trees he had found an orange on one branch and a lemon on another branch (which is not fo remarkable as what follows); as alfo, one of the fame fruit, half orange and half lemon; and fometimes 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 fee, with equal pleafure and aftonifhment, an account of the American apple, which, by a peculiar mode of budding (A), is half fweet and half four, half white and half red, without the leaft confufion of the refpective halves.

At Mr Mafon's, florift, Fleet-ftreet, oppofite the Bolt and Tun, there is a production now, September 1798, to be feen half peach and half nectarine. It has all the foftnefs and yellow down of the peach, and the fleek red fmoothnefs of the nectarine; fuppofed to be a *lufus naturæ*, but probably is rather the fportings of art than of nature, and which perhaps will be the caufe why we fhall in future fee many other fuch vegetable wonders, which, as we fee, were known to our anceftors.

ENNEADECATERIS, in chronology, a cycle or period of 19 folar years, being the fame 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 fhoulder of the baftion, or the angle made by the face and flank, otherwife called the angle of the epaule.

EPISCOPACY, the government of the church by diocefan bifhops. See *Encycl.*

SCOTCH EPISCOPALIANS, are a fociety of Chriftians, certainly as refpectable, if not fo numerous, as any other in the kingdom which diffents from the worfhip and difcipline of the eftablifhed church. For many years, however, the public worfhip of that fociety was profcribed by the legiflature; and there is reafon to fufpect that its real principles are not yet univerfally underftood. If this be fo, it furely becomes the editors of a work in which fome account is given of almoft every denomination of Chriftians down to the novel fect which ftyles its members BEREANS, to do juftice to the venerable remains of what was once the eftablifhed church of their native country.

I Eftablifhment of Epifcopacy in Scotland.

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 neither

(A) the manner in which the extraordinary nectarine-peach firft produced in this country was effected, was by inferting the bud of one fruit upon the ftock bearing a different fort.

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 Episcopalians; and public chapels, which had hitherto been prohibited, were everywhere built, and well frequented.

4
Introduction of the English liturgy.

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 Episcopalians 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 Episcopalians 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.

5
Sources of division among the Scotch Episcopalians.

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 surprise, 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,

* Supper of the Lord, Encycl.

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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 authorised by King Charles I. but likewise 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. 6

Revival of ancient usages.

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° 2. and 3. *Encycl.*); and their brethern, 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

(A) This very learned, though violent man, of whom the reader will find some account in the *Encyclopædia*, was, with Dr Hickes 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.

7 College of bishops.

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 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.

8 Those divisions healed.

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 styled *Primus Episcopus*, or more shortly *Primus*; but that he should not possess metropolitical 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.

9 Political opinions.

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

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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 dinstinguishing 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.

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

11 Toleration.

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.

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 Episcopalian clergymen 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, Nicane, 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.

12 Faith of the Scotch Episcopal church.

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* authorised 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 euchthe 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° 17. in this *Supplement*.

13 Their worship.

Thus have we given a short view of the distinguishing principles of what must surely be considered as a very respectable society of Christians, and the only reformed

14 English clergymen in Scotland.

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° 25—38.

EQUICURVE CIRCLE, the same with *CIRCLE of Curvature*, which see in this Supplement.

ERGETT EL KRANE, ERGETT Y'DIMMO } Two Abyssinian shrubs of 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 charecteristic 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 soot-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 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 oration 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.

Eton, Eudiometer.

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 Terras, 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° 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 into

(A) Or whatever the year may be.

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 friend's 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° 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 eliptic 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° 30′, others at 1° 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, to 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 cylindric 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.

* In all probability the *Harmonica* of the Abbé Mazzuchi.

Not long before he had read, in the Transactions of the Royal Society of Gottengen, 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 Leipsic 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 at 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 spunge, 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 harmoniea, 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 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.

Plate XXVIII. fig. 1. — Fig. 2. — Fig. 3.

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 bason 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 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 remittees? 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 Hamburgh, 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 $x^x = ab$, &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.

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 hypothenuse, 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.

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 them some share of the prey. *De mirabilibus auscultat.* cap. 128.

* *Hist Animal*, lib. ix. cap. 6.

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

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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 ſavour 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. Œder, 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. Obliged, with much diſcontent, to return, he herboriſed as he travelled, and enriched the Flora Suecica with ſeveral new diſcoveries.

A man in office at St Peterſburgh 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 Peterſburgh, 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 Kaſan in 1773, he there obtained permiſſion to go and uſe the baths of Kiſliar, from which he returned again to Kaſan at the end of the year, with his health apparently better.

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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 (knækebrœd), 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 cieling. 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 *Linnæi Amænitates Academicæ*.

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 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 autum 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, Farmer.

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 disappointment 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, insomuch 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 anarchists. 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 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.

FASCINATION, the art of bewitching, enchantment, an unseen inexplicable influence. Under the title SERPENS (*Encycl.* n° 22.) we have mentioned several instances of the fascinating power of the rattle-snake, 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 saw

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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, different 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 fusee. 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:

"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 smoothens 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 betwitch, 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, controverting, 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

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 stedfastly 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 venemous 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 effluvium 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 extends, 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 *."

* *American Philosophical Society.*

* *Lib.* 28. *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 fetor, 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 seeds 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,

 her

her motions are tremulous. She expofes herfelf to the moft imminent danger. Sometimes fhe approaches fo near the reptile that he feizes her as his prey. But this is far from being univerfally the cafe. Often fhe compels the ferpent to leave the tree, and then returns to her neft.

It is a well known fact, that among fome fpecies of birds, the female, at a certain period, is accuftomed to compel the young ones to leave the neft; that is, when the young have acquired fo much ftrength that they are no longer entitled to all her care. But they ftill claim fome of her care. Their flights are aukward, and foon broken by fatigue. They fall to the ground, where they are frequently expofed to the attacks of the ferpent, which attempts to devour them. In this fituation of affairs, the mother will place herfelf upon a branch of a tree or bufh, in the vicinity of the ferpent. She will dart upon the ferpent, in order to prevent the deftruction of her young: but fear, the inftinct of felf-prefervation, will compel her to retire. She leaves the ferpent, however, but for a fhort time, and then returns again. Oftentimes fhe prevents the deftruction of her young, attacking the fnake with her wings, her beak, or her claws. Should the reptile fucceed in capturing the young, the mother is expofed to lefs danger; for, whilft engaged in fwallowing them, he has neither inclination nor power to feize upon the old one. But the appetite of the ferpent tribe is great: the capacity of their ftomachs is not lefs fo. The danger of the mother is at hand when the young are devoured. The fnake feizes upon her: and this is the cataftrophe, which crowns the tale of fafcination!

FAUSSE Braye, in fortification, an elevation of earth, about three feet above the level ground, round the foot of the rampart on the outfide, defended by a parapet about four or five fathoms diftant from the upper parapet, which parts it from the berme and the edge of the ditch. The fauffe-braye is the fame with what is otherwife called *Chemin des rondes*, and *Baffe enceinte*; and its ufe is for the defence of the ditch.

FEATHER-edged, is a term ufed by workmen for fuch boards as are thicker on one edge, or fide, than on the other.

FELTING, the method of working up wool or hair into a kind of cloth or ftuff, without either fpinning or weaving it. In this country felting it little practifed except in hat-making; and as nine-tenths of thofe who are employed in the manufacturing of hats know nothing of the principles on which they proceed, the following obfervations on the mechanifm of felting muft to them be both agreeable and ufeful. They are by M. Monge, and taken from the *Annales de Chemie*.

If we examine, in a microfcope, human hair, wool, the hair of a rabbit, hare, beaver, &c. however great the magnifying power of the inftrument may be, the furface of each hair appears perfectly fmooth and even; or at leaft, if any inequalities are to be perceived, they feem rather to arife from fome difference in the colour and tranfparency of particular parts of thefe fubftances than from the irregularity of their furfaces; for their image, when viewed by a folar microfcope, is terminated by even lines, without any roughnefs. The furface of thefe objects, however, is by no means fmooth; on the contrary, it appears to be formed either of *lamellæ* which cover each other from the root to the point, pretty much in the fame manner as the fcales of a fifh cover the animal from the head to the tail; or, more probably, of zones placed one over the other, like what is obferved in the ftructure of horns: to this conformation it is that the fubftances here treated of owe their difpofition 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 fenfible of any friction or refiftance, nor can we diftinguifh any found; 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 fenfible of a refiftance which did not exift in the former cafe; a fort of tremulous motion is likewife produced, which is not only perceptible to the touch, but may alfo be diftinguifhed by the ear.

It is evident, therefore, that the texture of the furface of a hair is not the fame from the root towards the point as from the point towards the root; and that a hair, when grafped, muft offer more refiftance in fliding or moving progreffively towards the point than towards the root; *i. e.* in moving with its point foremoft.

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 progreffive motion takes place, and this motion is always towards the root. This effect does not at all depend on the nature of the fkin of the fingers or its texture; for if the hair be turned, fo that the point is placed where the root was, the movement then becomes contrary to what it was before; that is to fay, it is always directed towards the root.

What is obferved, in the above inftance, is entirely analogous to what happens when country children, by way of fport, introduce an ear of rye or barley between the wrift and the fhirt, the points of the beards of which are directed outwards. By the various motions of the arm, this ear, fometimes catching againft the fhirt, fometimes againft the fkin, takes a progreffive motion backwards, and foon 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 afperities upon thofe 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 ftalk. There is no doubt that it is the fame with refpect to hair; and that its furface is befet with afperities, 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 ufual means, on account of the extreme thinnefs of the hair; but if we place the hair in the bend of the hand, fo that the knot is in a line with the little finger, and, after grafping the hair by clofing the hand, we ftrike the fift feveral times againft the knee, the afperities of one end of the hair being now in a contrary direction to thofe 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 eafy to finifh untying it.

Thefe obfervations, which it would be ufelefs to multiply, relate to long hair, that having been taken as an example; but they apply with equal propriety to wool, furs,

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 contexture 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

for

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 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,

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 lour?

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 mimickry, 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 ſyren 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 cloſed 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 Canongate 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 Scottiſh 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 Touloufe 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 fineſt 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 Touloufe, in folio, 1679.

FERMENTATION is a chemical proceſs which has been already conſidered in the *Encyclopædia*, 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

Fermentation.

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 spirituosity 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 conlusion 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 spirituosity 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 spirituosity, so long as the action keeps within the pale of vinous fermentation.

"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.

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 shereef, 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 desart 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 desart 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 Mourzook 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 shereef 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 desart.

In the town or province of Mendrah is a large quantity of *trona*, 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 *albaicque*, 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 huadee, 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 Taffilet, who about 400 years since obtained the crown. Till the present century the kingdom was independent, when the Bashaw 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.

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 desart. 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 senna. 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*, senna, 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, senna, 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 Mourzook, 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.

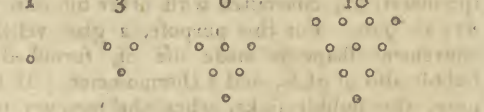
The above are all considered as different sorts of triangular numbers, being formed from an arithmetical progression whose common difference is 1. But if that common difference be 2, the successive sums will be the series of square numbers: if it be 3, the series will be pentagonal numbers, or pentagons; 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:

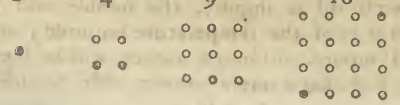
Triangles.

1 3 6 10



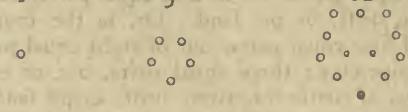
Squares.

1 4 9 16



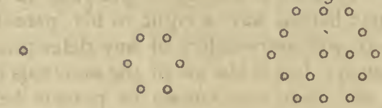
Pentagons.

1 5 12



Hexagons.

1 6 15



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 $1 \times 2 \times 3$, $2 \times 3 \times 4$, $3 \times 4 \times 5$, &c. by the first $1 \times 2 \times 3$. 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 $\frac{x \cdot \overline{x+1} \cdot \overline{x+2} \cdot \overline{x+3} \cdot \&c.}{1 \cdot 2 \cdot 3 \cdot 4 \cdot \&c.}$; 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 Windsor, Filter.

or other loam, of the fame quality with Windfor loam; and four equal parts, out of nine equal parts, of coarfe river, fea, drift, or pit fand. Or, in the fourth inftance, of four equal parts, out of eight equal parts, of tobacco-pipe clay; three equal parts, out of eight equal parts, of coarfe fea, river, drift, or pit fand; 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, thefe bafins, have a right to her patent, far be it from us to wifh our readers of any defcription to incroach upon it; but as the ufe of the materials of which her bafins are made was known to potters before fhe was born, they may certainly compound thefe materials in proportions different from hers, without doing her any legal injury. As fhe varies her own proportions fo much, we think it probable that fome proportion differing a little from them all, may anfwer the purpofe of filtering veffels equally well; and it is almoft needlefs to add, that with this precaution any potter may make fuch veffels, for which he would undoubtedly have a great demand.

A patent has likewife been granted to Mr Jofhua Collier of Southwark for a very ingenious contrivance for filtering and fweetening water, oil, and all other liquids. Of this contrivance, which combines the application of machinery with the antifeptic properties of charcoal (See CHEMISTRY n° 34. *Supplement*), we fhall give a detailed account.

Fifh-oil is one of the liquids which he had it particularly in view to free from all its impurities in fmell, tafte, and colour; and the chemical procefs employed by him for this purpofe, confifts in pouring a quantity of any fpecies of fifh-oil, or a mixture of different forts of fifh-oil, into any convenient veffel, which is to be heated to the temperature of 110 or 120 degrees of Fahrenheit's fcale, and then adding of cauftic mineral alkali, of the fpecific gravity commonly defcribed as 1.25, or of fuch ftrength that a phial containing 1000 grains of diftilled water will contain 1250 grains of thefe 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 ftand a fufficient time for the falts and fediments to fubfide; it is then drawn off into another veffel, containing a fufficient quantity of frefh burnt charcoal, finely powdered, or any other fubftance poffeffing antifeptic properties, in a powdered or divided ftate, with an addition of a fmall proportion of diluted fulphuric acid, fufficient only to decompofe the fmall quantity of faponaceous matter ftill fufpended in the oil, which appears by the oil becoming clear at the furface: the contents of this veffel are alfo agitated, and the coaly faline and aqueous particles left to fubfide; after which the oil is paffed through proper ftrainers, herein after defcribed, and is thereby rendered perfectly tranfparent and fit for ufe.

The principle of the improved ftrainers, or filtering machines, confifts in the means applied to combine hydroftatic preffure, which increafes according to the perpendicular height of the fluid, with the mode of filtering *per afcenfum*, thereby procuring the new and peculiar advantage that the fluid and its fediment take oppofite directions. A great advantage attending this invention is, that the dimenfions of the chamber in which the fediment is received, may be varied, while the filtering furface remains the fame. To adapt the machines not only to the purpofe of families, work-houfes, hofpitals, public charities, the navy, or the merchant fervice, but alfo to all the purpofes of oil-men, of diftillers, of the laboratory, the brewery, &c. chambers of various capacities muft be provided for the fediment and precipitated matter. With refpect to the oil-trade, the fpace required is very great, efpecially for fpermaceti, or Brafil bottoms. In the various purpofes of the laboratory, no limits can be fixed, but all dimenfions will be occafionally required: in diftilleries and breweries they may be fmaller in proportion; and in that defigned for water and for domeftic ufe, a very fmall chamber will be fufficient. When water is to be fweetened, or freed from any putrid or noxious particles, it paffes, in its way to the filtering chamber, through an iron-box, or cylinder, containing charcoal finely powdered, or any other antifeptic fubftance infoluble in water, the water being forced into it by hydroftatic preffure, through a tube of any fufficient height. This box has two apertures to receive and deliver the fluid, and thefe are opened and clofed by cocks, or fcrews, or any other method ufed for fuch purpofes; and being affixed to the machine by other fcrews, may be eafily detached from the fame. Thus, whenever the charcoal begins to lofe its antifeptic properties, the box is removed and heated till it is red hot; by which means the foreign matter efcapes through the fmall apertures; after which the box is cooled, and the charcoal becomes fweet, pure, and equally fit for ufe as at firft, though the procefs be ever fo often repeated.

Another part of the invention confifts in filtering machines in the form of ftills, in which charcoal may be repeatedly burned after any fluid fubftances have paffed through it, for the purpofe of freeing them either from putrid or noxious particles, or of difcharging their colouring matter; which filtering ftills are fo contrived, that the fluid may pafs through in any quantity, without difplacing the charcoal: the part of the fluid remaining interfperfed among the charcoal, may be driven over by heat, and be employed for many inferior purpofes of the arts or manufactures. Laftly, the heat may be raifed fo as to purify the charcoal, as has been before defcribed in the machines for water. The flue of thofe ftills is fo conftructed that water may be employed to cool them without the lofs of time requifite for their gradually parting with their heat to the furrounding atmofphere, fo as to be fit for a fubfequent 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 inftruments for afcertaining the comparative qualities of oils, which depend in part on the principle of their fpecific gravities; fpermaceti oil, contrafted with other fifh oils, being as 875 to 920. For this purpofe, a glafs veffel of any convenient fhape is made ufe of, furnifhed with a bubble alfo of glafs, and a thermometer. If the oil is pure, this bubble finks, when the mercury rifes to a certain ftandard, by the application of the hand, or any other heat to the veffel containing the oil. If the fpermaceti oil is impure, the bubble will ftill float, though it is of the temperature required; and the degree of impure, or foreign matter, will be fhewn by the ftate of the thermometer at which the bubble finks.

Filter.

To determine what tendency oils ufed for burning have to congeal in cold weather, a freezing mixture is put in a phial of thin glafs, or any other convenient veffel; into this a thermometer is immerfed, and a fingle drop of the oil, under experiment, fuffered to fall on the outfide of the veffel, where it immediately congeals: as the cold produced by the mixture gradually ceafes, it is eafy to obferve by the thermometer at what point of temperature the oil becomes fluid, and runs down the fide of the glafs.

Plate XXIII.

A fhort defcription of this apparatus will make its principles plain to every reader. A (fig. 1.) is the ciftern into which the water or other liquor to be filtered is put. B B is a tube opening into the bottom of the ciftern 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 bafon rifing above the level of the chamber and receiving the filtered liquor. E, The fpout by which it runs off into a pitcher or other veffel. F, Another fpout furnifhed with a cock to draw off the foul water from the chamber when neceffary. GGG, The air tube, which begins above the level of the chamber, is covered with a button, which faves the leather from being cut, and has a fmall lateral aperture for the air to be carried off. This pipe paffes along the bottom and up the fide, and rifing above the level of the water in the ciftern, is there clofed, except a fmall lateral aperture through which the air efcapes. H, A guard or rim with crofs bars put over the leather to keep it from being forced up by the water. It is faftened down by means of two notches on oppofite fides of the guard, by which it locks into two ftaples rivetted into the bottom of the bafon. I, The lid fliding down to cover the water from duft, and fufpended at pleafure by means of KK, two fprings on each tube for that purpofe. 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, fo that the fluid may pafs through the fame into the cylinder, from whence it enters the chambers at P, fo as to be filtered through the leather as before defcribed. RR, Collars which may be unfcrewed at pleafure, fo 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 ciftern containing the oil to be filtered, and fupplying a tube of fufficient height for the hydroftatic preffure to operate. BB, A main tube of wood, tin, leather, or cloth, to which any number of bags, of the fize and fhape of corn facks, or any CC, convenient fize or fhape may be connected. Thefe are bound to DDD, ftraight double iron bars, furnifhed with a hinge at one end and a fcrew 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 cafk or ciftern, into which the fluid is put which paffes down. B, A tube fitted into the fame, through which it enters. C, An iron ftill, or ftill of any other fubftance capable of fuftaining heat, full of finely powdered and fifted charcoal, through the head of which the fluid paffes into any receiver. D, A fire-place of any conftruction to drive over the fluid remaining interfperfed among the charcoal, and alfo to purify the charcoal by an increafe of temperature when required. E, A cock to let water into the flues to cool the apparatus for a fubfequent operation.

Fig. 4. The trial glafs with its thermometer.

Fire.

FIRE. See that article *Encycl.* and Caloric and Combustion, *Chemistry-Index* in this *Suppl.*

Extinction of Fire is fometimes a matter of fo much confequence, that every thing which promifes to be effectual for that purpofe is worthy of attention. In the nineteenth number of Mr Nicholfon's Journal of Philofophy, Chemiftry, and the Arts, we have the following compofition for extinguifhing fire, invented by M. Von Aken.

Burnt alum - - - - -	pounds	30
Green vitriol powdered - - -		40
Cinabrefe or red ochre in powder -		20
Potter's clay, or other clay, alfo powdered		200
Water - - - - - - -		630

With 40 meafures of this mixture an artificial fire was extinguifhed under the direction of the inventor by three perfons, which would have required the labour of 20 men and 1500 meafures of common water. Sig. Fabbroni was commiffioned to examine the value of this invention, and found in his comparative trials with engines of equal power, worked by the fame number of men, that the mixture extinguifhed the materials in combuftion in one fixth part lefs time, and three eighths lefs of fluid than when common water was ufed. He obferved, as might indeed have been imagined from the nature of the material, that the flame difappeared wherever the mixture fell, and that the faline, metallic, and earthy matters, formed an impenetrable lute round the hot combuftible matter, which prevented the accefs of the air, and confequently the renewal of the deftructive procefs.

This recipe, Mr Nicholfon informs us, is taken from N° 85. of *Giornale Letterario di Napoli*, in which it was inferted in the form of a letter from Sig. Fabbroni to Sig. D. Luigi Targioni of Naples; and the author of the letter eftimates the price of the compofition at about one halfpenny per pound.

The reafon affigned by Mr Nicholfon for giving this abridged account a place in his valuable work, will be admitted by him and the public as a fufficient reafon for our adopting it into our's. It is, that fuch inventions are worthy of the attention of philofophers and economifts, even though in the firft applications they may prove lefs advantageous than their inventors may be difpofed to think. It is fcarcely 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 fufficient ftore of the materials would be kept in readinefs; fince at this rate the expenditure for an hour would demand a provifion to the amount of L. 210 fterling. But in country places the procefs, or fome variation of it, might be applied with fufficient profit in the refult; more efpecially if it be confidered that common falt or alum, or fuch faline matter as can be had and mixed with the water, together with clay, chalk, or lime, ochreous earth or common mud, or even thefe laft without any falt, may anfwer the purpofe of the

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 the reader's notice *.

* Phil. Mag. 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 expansion 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

the chain of the Pyrenees in echoes, for the diftance of 15 miles. It continued about four minutes, becoming gradually more remote, and always weaker; and at the fame time we perceived a ftrong fmell of fulphur.

"While we were endeavouring to point out to fome perfons prefent the place where the meteor had divided itfelf, we obferved a fmall whitifh cloud, which arofe perhaps from the vapour of it, and which concealed from us the three ftars of the Great Bear, lying in the middle of thofe forming the femicircle. With fome difficulty, however, we could at laft diftinguifh thefe ftars again behind the thin cloud. There arofe, at the fame time, a frefh gentle breeze.

"From the time that elapfed between the burfting of the ball and the explofion which followed, I was inclined to think that the meteor was at the height of at leaft feven or eight miles, and that it fell four miles to the north of Mormes. The latter part of my conjecture was foon confirmed by an account which we received, that a great many ftones had fallen from the atmofphere at Juliac, and in the neighbourhood of Barbotan. One of thefe places lies at the diftance of about four miles to the north of Mormes, and the other at about the diftance of five to the north-northweft."

M. de Carrits Barbotan, the friend who was with the Profeffor in the court and garden of Mormes when the meteor firft attracted their attention, was at Juliac two days afterwards, and confirmed to him the truth of this circumftance. It appeared, likewife, from the account of feveral intelligent perfons, highly worthy of credit, that the meteor burft at a little diftance from Juliac, and that the ftones which fell were found lying in a fpace almoft circular, about two miles in diameter. They were of various fizes. Some were *feen to fall*, which, when found, weighed 18 or 20 pounds, and which had funk into the earth from two to three feet. M. de C. Barbaton tranfmitted one weighing 18 pounds to the Academy of Sciences at Paris; and M. Bandin was told, that fome were found which weighed even 50 pounds. He examined a fmall one, and found it very heavy in proportion to its fize: it was black on the outfide; of a greyifh colour in the infide, and interfperfed with a number of fmall fhining metallic particles. On ftriking it with a piece of fteel, it produced a few fmall dark red fparks, not very lively. A mineralogift, to whom a like piece of ftone from the fame meteor was fhewn at Paris, defcribed it as a kind of grey flag mixed with calcareous fpar, the furface of which exhibited vitrified blackifh calx of iron. The Profeffor was told alfo, that fome ftones were found totally vitrified.

Such (fays 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 atmofphere.

According to all the obfervations hitherto made with any accuracy on fire-balls, the height at which they were firft perceived was always very confiderable, and by comparing the angles under which they were feen from different points, often 19 German miles, and even more; their velocity, for the moft part, feveral miles in a fecond; and their fize always very great, often a quarter of a mile, and even more, in diameter. They were all feen to fall moftly in an oblique direction; not one of them ever proceeded upwards. All of them have appeared under the form of a globular mafs, fometimes a little extended in length, and highly luminous; having behind it a tail, which, according to every appearance, was compofed of flames and fmoke. All of them burft after they were feen to move through a large fpace, fometimes over feveral diftricts, with an explofion which fhook every thing around. In every inftance where there has been an opportunity of obferving the fragments that fell after they burft, and which fometimes have funk to the depth of feveral feet into the earth, they were found to confift of fcorious maffes, which contained iron in a metallic or calcined ftate, pure, or elfe mixed with different kinds of earth and fulphur. All the ancient and modern accounts, written partly by naturalifts and partly by others, are fo effentially fimilar, that the one feems to be only a repetition of the other. This conformity in accounts, the authors of which knew nothing of thofe given by others, and who could have no intereft in fabricating fimilar tales, can fcarcely have arifen from accident or fiction, and gives to the related facts, however inexplicable many of them may feem, every degree of credibility.

In the third volume of Pallas's Travels, we have an account of a mafs of iron difcovered by him in Siberia, which Dr Chladni confiders as having been undoubtedly a fire-ball, or the fragment of a fire-ball. This problematical mafs was found between Krafnojarfk and Abekanfk in the high flate mountains, quite open and uncovered. It weighed 1600 pounds; had a very irregular and fomewhat compreffed figure like a rough granite; was covered externally with a ferruginous kind of cruft; and the infide confifted of malleable iron, brittle when heated, porous like a large fea fponge, and having its interftices filled with a brittle hard vitrified fubftance of an amber yellow colour. This texture and the vitrified fubftance appeared uniformly throughout the whole mafs, and without any traces of flag or artificial fire.

Dr Chladni fhews, with a great deal of ingenuity, that this mafs neither originated by the wet method, nor could have been produced by art, the burning of a foreft, by lightning, or by a volcanic eruption. It appears to him, therefore, in the higheft degree probable, that it is of the fame nature with fire-balls, or, as they have fometimes been called, *flying dragons*. The Tartars, as we are informed by Pallas, confidered this mafs as a facred relic which had dropped down from heaven; and this circumftance Dr Chladni confiders as no flight confirmation of his opinion, which he farther fupports by the following reafonings:

"1. As fire-balls confift of denfe and heavy fubftances, which, by their exceedingly quick movement, and the friction thence excited by the atmofphere, become electric, are reduced to a ftate of ignition, and melted by the heat, fo that they extend to a great fize, and burft; it thence follows, that in places where fragments, produced by the burfting of a fire-ball, have been found, fubftances endowed with all thefe properties muft alfo have been found. Iron, however, the principal component part of all the maffes hitherto found (and he fpeaks of many befides that of Pallas), poffeffes all thefe properties in a very eminent degree. The weight and toughnefs of the principal component parts of fire-balls, which

which muſt be very conſiderable, ſince, with the greateſt poſſible diſtention, 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 foſſile 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 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

which we can form of Nature in *this fenfe*, "to fuppofe that a large quantity of material particles, either on account of the *diftance*, or becaufe prevented by a *ftronger movement* in another direction, have not united themfelves to the larger accumulating mafs of a new world, but remained infulated, and impelled by fome fhock, have continued their courfe through infinite fpace, &c." Is there any diftance to which God cannot reach, or any movement fo ftrong as to refift his power? Our author's language is indeed confufed, and probably his ideas were not very clear. When he fpeaks of the particles of matter being at firft difperfed through infinite fpace, and afterwards united by the power of attraction, he revives the queftion which was long ago difcuffed between Newton and Bentley, and difcuffed in fuch a manner as fhould have filenced for ever the bablings of thofe who form worlds by attraction.

"The hypothefis (fays Newton) of matter's being at firft evenly fpread through the heavens, is, in my opinion, inconfiftent with the hypothefis of innate gravity without a fupernatural power to reconcile them; and therefore infers a Deity. For if there be innate gravity, it is impoffible now for the matter of the earth, and all the planets and ftars, to fly up from them, and become evenly fpread through all the heavens, without a fupernatural power; and certainly that which can never be hereafter without a fupernatural power, could never be heretofore without the fame power." Dr Chladni, indeed, does not fay that his particles of matter were *evenly* difperfed through infinite fpace; but fuch muft be his meaning, if he has any meaning: for matter *unevenly* difperfed muft, by an innate attraction, be united as foon as it exifts, and fo united as not to leave fmall fragments of it to wander, we know not why, through the tracklefs void. Turn matter on all fides, make it eternal or of late production, finite or infinite, there can be no regular fyftem produced but by a voluntary and meaning agent; and therefore, if it be true that fire-balls are maffes of denfe matter, coeval with the planetary fyftem, exifting in the celeftial regions, and thence conveyed to our earth, they muft have been formed, and their motions impreffed upon them, by the Author of Nature for fome wife purpofe, though by us that purpofe may never be difcovered. One thing feems pretty clear, that wherever they may be formed, the phenomena attending their burfting, account fufficiently for the notions of thunderbolts which have been generally entertained in all ages, and in every country.

*Greek-*FIRE (fee *Wild-*FIRE, *Encycl.*). In the fecond volume of Mr Nicholfon's Philofophical Journal, we have the following receipt for making this compofition, taken from fome manufcripts of Leonard de Vinci, who flourifhed in the end of the fifteenth and beginning of the fixteenth centuries, and who appears to have advanced far before his contemporaries in phyfical fcience. Take the charcoal of willow, nitre, brandy, refin, fulphur, 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 fpikes. Thefe balls, being fet on fire, are thrown into the enemy's veffels. It is called the Greek fire, and is a fingular compofition, for it burns even upon the water. Callinicus the architect taught this compofition to the Romans (of Conftantinople), who derived great advantage from it, particularly under the emperor Leo, when the Orientals attacked Conftantinople. A great number of their veffels were burned by means of this compofition.

The compofition of the Greek fire thus given by Vincini is found in nearly the fame words in fome of the writings of Baptifta Porta; whence it appears that both authors derived their information from the fame fource. A compofition which burnt without accefs to the atmofphere could not fail to fill the minds of our forefathers with wonder; but the modern difcoveries in chemiftry have difclofed the fecret, by fhewing, that the combuftion is carried on by means of the oxygen contained in the nitre.

Rafant or *Razant* FIRE, is a fire from the artillery and fmall arms, directed parallel to the horizon, or to thofe 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 cafe each fquadron or battalion takes the fire from that on its right, from the right of the firft line to the left, and from the left to the right of the fecond line, &c.

FISHING, the art of catching fifh. See ANGLING, FISHERY, and FISHING, &c. *Encycl.*

Chinefe FISHING. We venture to give this appellation to fome very ingenious contrivances of the people of China for catching in their lakes, not only fifh, but water-fowl. For the purpofe of catching fifh they have trained a fpecies of pelican, refembling the common corvorant, which they call the *Leu-tze*, or fifhing-bird. It is brown, with a white throat, the body whitifh beneath, and fpotted with brown; the tail is rounded, the irides blue, and the bill yellow. Sir George Staunton, who, when the embaffy was proceeding on the fouthern branch of the great canal, faw thofe birds employed, tells us, that on a large lake, clofe to the eaft fide of the canal, are thoufands of fmall boats and rafts, built entirely for this fpecies of fifhery. On each boat or raft are ten or a dozen birds, which, at a fignal from the owner, plunge into the water; and it is aftonifhing to fee the enormous fize of fifh with which they return, grafped within their bills. They appeared to be fo well trained, that it did not require either ring or cord about their throats to prevent them from fwallowing any portion of their prey, except what their mafter was pleafed to return to them for encouragement and food. The boat ufed by thefe fifhermen is of a remarkable light make, and is often carried to the lake, together with the fifhing birds, by the men who are there to be fupported by it.

The fame author faw the fifhermen bufy on the great lake Wee-chaung-hee; and he gives the following account of a very fingular method practifed by them for catching the fifh of the lake without the aid of birds, of net, or of hooks.

To one fide 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 fo placed that the painted board is turned to the moon, from whence the rays of light ftriking on the whitened furface, give to it the appearance of moving water; on which the fifh being tempted to leap as on their element, the boatmen, rifing with a ftring the board, turn the fifh into the boat.

Water-fowl are much fought after by the Chinefe and

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 Ciènega de Tesias.

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.

Fistula, Flank.

"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 supperative 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 fichant, or the greater and

and less lines of defence; or the part of the curtain between the flank and the point where the fichant 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*.

Fichant 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 diameter 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 practically 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.

termined, 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.

" 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 re-action 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 homogeneal 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 mixtilineal

Plate XXVIII.

Floating.

tilineal as in fig. 3. in all which MM reprefents the line of floatation when upright, and EF that when inclined at any angle MXE; alfo G reprefents the centre of gravity of the whole veffel, and R that of the part immerfed.

"If the veffel be loaded quite up to the line AB, and the fpecific gravity of the boat and burden be the fame, then the point G is fimply the centre of gravity of the fection ABCD; but if not, the centres of gravity of the boat and burden muft be found feparately, and reduced to one by the common method, namely, by dividing the fum of the momenta by the fum of weights, or areas, which in this cafe are as the weights. The point R is always the centre of gravity of the fection MMCD, which, if confifting of different figures, muft alfo be found by dividing the fum of the momenta by the fum of the weights as common. Thefe two points being found, the next thing neceffary is to determine the area of the two equal triangles MXE, MXF, their centres of gravity *o*, *o*, and the perpendicular projected diftance *n n* of thefe points on the water line EF. This being done, through R, and parallel to EF, draw RT = a fourth proportional to the whole area MMCD, either triangle MXE or MXF, and the diftance *n n*; through T, and at right angles to RT or EF, draw TS meeting the vertical axis of the veffel in S the metacentre; alfo 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 ftability of the veffel, which will be pofitive, nothing, or negative, according as the point S is above, coincident with, or below, the point G. If now we fuppofe W to reprefent the weight of the whole veffel and burden (which will be equal to the fection MMCD multiplied by the length of the veffel), and P to reprefent the required weight applied at the gunwale B to fuftain the veffel at the given angle of inclination; we fhall always have this proportion: as VS : SW : : W : P; which proportion is general, whether SW be pofitive or negative; it muft only, in the latter cafe, be fuppofed to act upward to prevent an overturn.

"In the rectangular veffel, of given weight and dimenfions, the whole procefs is fo evident, that any farther explanation would be unneceffary. In the trapezoidal veffel, after having found the points G and R, let AD, BC be produced until they meet in K. Then, fince the two fections MMCD, EFDC are equal, the two triangles MMK, EFK are alfo equal; and therefore the rectangle EK × KF = KM × KM = $\overline{KM}^2$; and fince the angle of inclination is fuppofed to be known, the angles at E and F are given. Confequently, if a mean proportional be found between the fines of the angles at E and F, we fhall have the following proportions:

"As the mean proportional thus found : fine ∠E : : KM : KF, and as the faid mean proportional : fine ∠F : : KM : KE; therefore ME, MF become known: from whence the area of either triangle MXE or MXF, the diftance *nn*, and all the other requifites, may be found.

"In the mixtilineal fection, 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; alfo let the two curvelinear parts be circular quadrants of two feet, or 24 inches radius each. Then the area of the two quadrants = 904·7808 fquare inches, and the diftance of their centres of gravity from the bottom = 13·8177 inches very nearly; alfo the area of the included rectangle *abie* = 1440 fquare inches, and the altitude of its centre of gravity 12 inches; in like manner, the area of the rectangle AB*cd* will be found = 5184 fquare inches, and the altitude of its centre of gravity 48 inches: therefore we fhall have

Momentum of the two quad.	= 904·7808	×	13·8177	=	12501·98966016
Moment. of the rectan. *abie*	= 1440·	×	12	=	17280·
Moment. of the rectan. AB*cd*	= 5184·	×	48	=	248832·
	7528·7808				278613·98966016

"Now the fum of the momenta, divided by the fum of the areas, will give $\frac{278613\cdot98966016}{7528\cdot7808} = 37\cdot006$ inches, the altitude of G, the centre of gravity of the fection ABCD above the bottom. In like manner, the altitude of R, the centre of gravity of the fection MMCD, will be found to be equal $\frac{123093\cdot98966016}{4936\cdot7808}$ = 24·934 inches; and confequently their difference, or the value of GR = 12·072 inches, will be found.

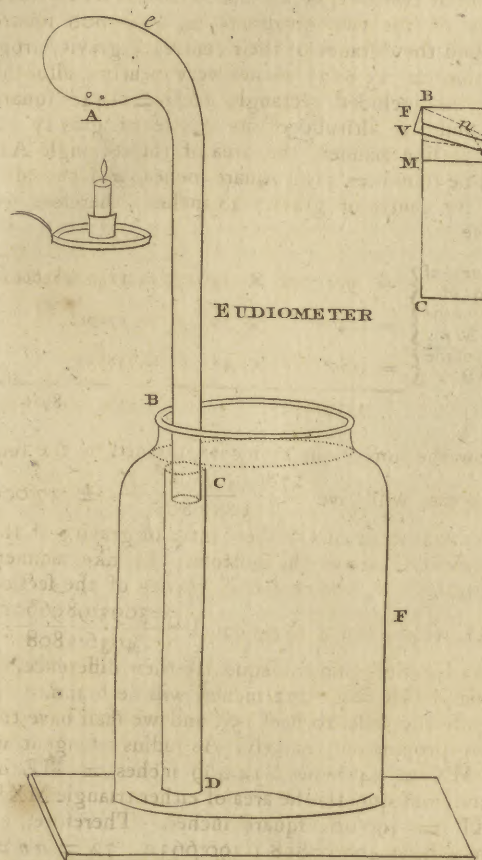
Suppofe the veffel to heel 15°, and we fhall have the following proportion; namely, As radius : tangent of 15° : : MX = 54 inches : 14.469 inches = ME or MF; and confequently the area of either triangle MXE or MXF = 390·663 fquare inches. Therefore, by theorem 4th, as 4936·7808 : 390·663 : : 72 = *nn* = $\frac{2}{3}$ AB : 5·6975 inches = RT; and, again, as radius : fine of 15° : : 12.072 = GR : 3·1245 inches = RN; confequently RT—RN = 5.6975—3·1245 = 2·573 inches = SW, the ftability required.

"Moreover, as the fine of 15° : radius : : 5·6975 = RT : 22·013 = RS, to which, if we add 24·934, the altitude of the point R, we fhall 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 diftance BS is found = 59·529 inches very nearly, and the angle SBV = 80°—06′—42″; from whence SV = 58·645 inches.

Again: Let us fuppofe the mean length of the veffel to be 40 feet, or 480 inches, and we fhall have the weight of the whole veffel equal to the area of the fection 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 fuftain the veffel at the given inclination. Therefore a veffel of the above dimenfions, 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 fuppofed to act perpendicularly on the gunwale at B; but if the veffel is navigated by fails, the centre velique muft be found; with which, and the angle of deflection, the projected diftance thereof on the line SV may be obtained; and then the power, calculated as above neceffary



EUDIOMETER

FLOATING BODIES

Fig. 1.

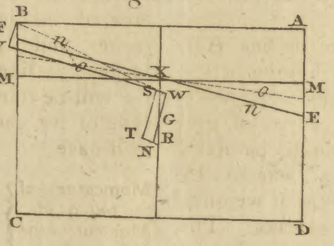


Fig. 2.

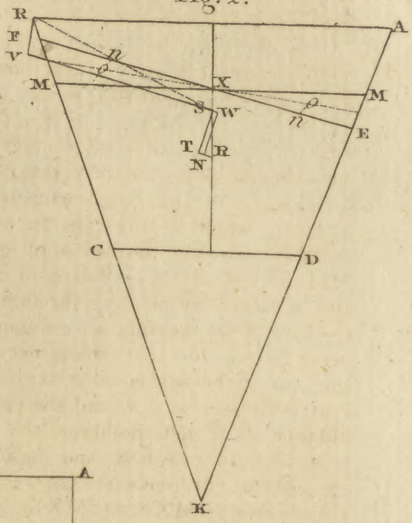
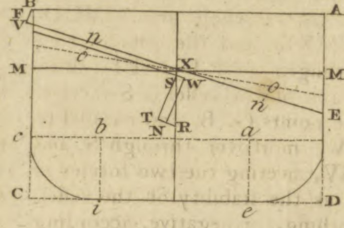


Fig. 3.



EUPHORBIA

Fig. 1.

Fig. 2.

Fig. 3.

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 *Encyclopædia.*

The subject of this memoir, who was their fourth son, acquired, as well as his brother, the rudiments of classical learning at the grammer 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 sour 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

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 mentioned 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.

Fordyce, Formula.

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.

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 abscis 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, Bossu's, and Reidsel'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.

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 authorised 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

ritated his temper and offended his pride, becaufe, forfooth, the Prince of Heffe-Caffel would not by *him* be perfuaded to relinquifh it, that he did every thing in his power, we are told, to withdraw himfelf from a fituation fo unfuitable to a thinking being. Every thing in his power! Did the Prince retain him in the univerfity contrary to his inclination? The univerfity of Caffel muft be contemptible indeed, if the prelections of fuch a man as George Forfter were of fuch confequence to it.

He got away, however; and the fenate of Poland having offered him a chair in the univerfity of Wilna, Forfter 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 fuccours of which he ftood in need, he could not be long happy in a femi-barbarous nation, in which liberty was fuffered to expire under the intrigues of Ruffia and Pruffia.

On this, with wonderful confiftency, the man who could not endure the defpotifm of Heffe, or even the ariftocracy of England, accepted of the propofitions of that friend to liberty Catharine II.; who, jealous of every fpecies of glory, wifhed to fignalize her reign, by procuring to the Ruffian nation the honour of undertaking, after the example of England and France, a new voyage of difcovery round the world. Unfortunately for the progrefs of knowledge, the war with the Ottoman Porte occafioned the mifcarriage of this ufeful project.

But Forfter could not long remain in obfcurity. The different publications with which he occafionally enriched natural hiftory and literature, encreafed his reputation. The Elector of Mentz accordingly appointed him prefident of the univerfity of the fame name; and he was difcharging the functions of his new office when the French troops took poffeffion of the capital. This philofophical traveller, who had ftudied fociety under all the various afpects arifing from different degrees of civilization; who had viewed man fimple and happy at Otaheite;—an eater of human flefh in New Zealand, corrupted by commerce in England, depraved in France by luxury and atheifm, in Brabant by fuperftition, and in Poland by anarchy;—beheld with wild enthufiafm the dawnings of the French revolution, and was the firft, fays M. Pougens, to promulgate republicanifm in Germany.

The *Mayencois*, who had formed themfelves into a national convention, fent him to Paris, in order to folicit their *reunion* with the French republic. But, in the courfe of his miffion, the city of Mentz was befieged and retaken by the Pruffian troops. This event occafioned the lofs of all his property; and what was ftill more difaftrous, that of his numerous manufcripts, which fell into the hands of the Prince of Pruffia.

Our biographer, after conducting his hero through thefe fcenes of public life, proceeds to give us a view of his domeftic habits and private principles. He tells us, that he formed a connection (whether a marriage or not, the ftudied ambiguity of his language leaves rather uncertain) with a young woman named *Therefa Hayne*, who, by the illumination of French philofophy, had divefted herfelf of all the prejudices which, we truft, the ladies of this country ftill confider as their honour, as they are certainly the guardians of domeftic peace. Mifs Hayne was indignant at the very *name of duty*. With Eloifa fhe had taken it into her head that

> Love, free as air, at fight of human ties,
> Spreads his light wings, and in a moment dies.

She was frank enough, however, fays our author, to acknowledge the errors of her imagination; and from this expreffion, and his calling her afterwards Forfter's wife, we are led to fuppofe that fhe was actually married to him. But their union, of whatever kind, was of fhort duration. Though the lady is faid to have been paffionately attached to celebrated names, the *name* of George Forfter was not fufficient to fatisfy her. He foon ceafed, we are informed, to *pleafe* her; fhe therefore transferred her affections to another; and, as was very natural for a woman who was indignant at the name of duty, fhe proved falfe to her hufband's bed. Forfter, however, pretended to be fuch a friend to the *modern* rights of men and women, that he defended the character of his Therefa againft crowds who condemned her conduct. Nay, we are told, that he confidered himfelf, and every other hufband who ceafes to pleafe, as the *adulterer of nature*. He therefore laboured ftrenuoufly to obtain a divorce, to enable Therefa Hayne to efpoufe the man whom fhe preferred to himfelf. Strange, however, to tell, the prejudices even of this Cofmopolite were too ftrong for his principles. While he was endeavouring to procure the divorce, he made preparations at the fame time, by the ftudy of the oriental languages, to undertake a journey to Thibet and Indoftan, in order to remove from that part of the world, in which both his heart and his perfon had experienced fo fevere a fhock. But the chagrin occafioned by his misfortunes, joined to a fcorbutic affection, to which he had been long fubject, and which he had contracted at fea during the voyage of circumnavigation, abridged his life, and prevented him frem realifing this double project. He died at Paris, at the age of 39, on the 13th of February 1792.

This is a ftrange tale; but we truft it will not prove ufelefs. The latter part of it at leaft fhows, that when men diveft themfelves of the principles of religion, they foon degenerate from the dignity of philofophers to the level of mere fenfualifts; and that the woman who can, in defiance of decorum and honour, transfer her affections and her perfon from man to man, ranks no higher in the fcale of being than a female brute of more than common fagacity. It fhews likewife, that the contempt of our modern fages for thofe 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 Forfter, though he was fuch a zealous advocate for liberty and equality, as to vindicate the adultery of his wife; yet felt fo fenfibly the wound which her infidelity inflicted on his honour, that he could not furvive it, but perifhed, in confequence, in the flower of his age.

Royal FORT, is one whofe line of defence is at leaft 26 fathoms long.

Star Fort, is a fconce or redoubt, conftituted by reentering and faliant angles, having commonly from five to eight points, and the fides 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 Massilua 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 14¼th ounces; whereas a common brick weighed 5 pounds 6¾ths 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; Wassela beyond the upper part of the Niger; and Massina lower down on the same river, and joining to Tombuctoo on the west.

Foulahs, Francais.

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 Rennels 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° 37′ N. Lat. and in 139° 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;

Francais. 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 bason 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 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. Francais.

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 sallow, 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.

Francais. 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, *fletans* or *faitans*, 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." Francais.

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 turbet. Its back is covered with small scales; and those which are taken in Europe are much less than the fletans of Port des Français titioners 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. Chesnut 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.

FRE'GATES 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.

FRICTION, 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 MECHANICS, 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 $52\frac{1}{4}$ inches in 4″; for by the beat of the clock, and the sound 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

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 $41\frac{3}{4}$ 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; $r = 16\frac{1}{12}$ 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 $F = M - \frac{\overline{M \times W} \times S}{r\,t^2}$. To exemplify this, let us take the case of the last experiment, where $M = 7$, $W = 25\frac{3}{4}$, $S = 4\frac{7}{12}$ feet, $t = 4''$; hence $F = 7 - \frac{32\frac{3}{4} \times 4\frac{7}{12}}{16\frac{1}{12} \times 16} = 6.417$; consequently 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 $\frac{1}{600}$dth part of the whole.

5. We come, in the next place, to determine whether friction, *cæteris 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

3 oz. deſcribed 20 inches in 2″; by loading the body with 10 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, *cæteris 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 $33\frac{1}{2}$ 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 $37\frac{1}{2}$ 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 $\frac{5}{8}$ths 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 $1\frac{3}{8}$ 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 $\frac{1}{4}$ 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, $5\frac{2}{7}$ 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 $7\frac{1}{3}$ 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, $5\frac{1}{8}$ inches, and on the edge $6\frac{1}{12}$ 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, $4\frac{1}{7}$ and $7\frac{7}{10}$ 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 $12\frac{3}{4}$ 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. 2*dly*, 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 $\frac{1}{3}$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° 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 corollaries 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 purpose 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° 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°. A mixture consisting of muriat of lime 2 lb. at + 33°, and the same weight of snow at + 32° gave — 42° (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° to + 5, another mixture, the same in every respect as the last, was made, which gave, on trial with the thermometer, — 43°. 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°. 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°, and which still remained in the metallic vessel, was now added snow, uncompressed and free from moisture, at the usual temperature of + 32°. In less than three minutes the mixture gave a temperature of — 62°: 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°, was now, by the means employed before, cautiously put into the last made mixture of the temperature of — 62°. A hoop with net-work 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. him 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.

* The Philoſophical Magazine.

Frio ‖ Fuel

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 Count 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,

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 obſervations, 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.* nos 849 and 850.
Fulminating Silver.

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 matraſs. The ſolution being poured off, the reſiduary black powder and the matraſs 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 prepared

Fulminating.

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 poximity 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 c^x, is each of them a function of the quantity x.

FURD-Y-HUCKEECUT, 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,

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 confuſed, 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.

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.

GALVANISM.

1 Galvaniſm improperly called *animal electricity*.

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 galvaniſm.

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 having 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 lightned. 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,

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. 6 Animal and excitatory arcs.
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.

7 Experiments of the French inſtitute.

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).

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*. *2d*, Account of what has been obſerved of the nature and the different diſpoſitions of the *excitatory arc*. *3d*, 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.

8 On the animal arc.

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:

9 Inferences.

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

(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 nimal arc; for the mufcles are always more or lefs interfected by the nerves; and are, confequently, in part, a nervous organ.

3. All the parts of the animal arc muft be either mutually continuous, or at leaft contiguous to one another. But even contiguity is fufficient to enable the galvanic phænomena to take place.

4. The fection or ligature of a nerve interrupts not the galvanic phenomena, if the parts which are cut afunder or bound up ftill remain in clofe contiguity to one another.

5. No diverfity of the parts forming the animal arc, though thefe be taken from different parts of the fame animal, or even from different animals, will have power to impair its galvanic fufceptibility, provided only that thefe parts be ftill mutually contiguous.

6. If the *integrity* or galvanic fufceptibility of the animal arc be fufpended by the feparation of any of its parts to fome diftance from one another, it may be reftored by the interpofition of fome fubftances, not of an animal nature, between the divided parts. Metallic fubftances are in particular fit for this ufe. But the mutual contiguity of all the fubftances entering into the compofition of the arc muft ever be carefully preferved. Mr Humboldt difcovered that a bit of frefh morelle (*Helvella mitra Linn.*) will fupply the place of a part of the nerve.

7. The mufcular organs which indicate, by contraction, the prefence of the galvanic influence, are always thofe in which the nerves of a complete animal arc have their ultimate termination.

From this it follows, that the mufcles affected by galvanifm are always thofe correfponding to that extremity of the arc which is the moft remote from the origin of the nerves of which it is compofed.

8. When all the nerves of the animal arc originate towards one of its extremities, then only thofe mufcles which correfpond with the oppofite extremity are fufceptible of galvanic convulfions.

9. When an animal arc confifts of more than one fyftem of different nerves, which have all their origin about the middle of the arc, then will the mufcles of thefe feveral fyftems of nerves be moved alike at both the extremities of the arc.

10. It feems likewife to appear, from a variety of thefe experiments, that the opinion of thofe is inadmiffible, who afcribe the phænomena of galvanifm to the concurrence of two different and reciprocally correfponding influences, one belonging to the nerve, the other to the mufcle, and who compare the relations between the nerve and the mufcle, in thefe phænomena, to thofe between the interior and the exterior coating of the Leyden phial.

11. It appears, laftly, that the covering of the epidermis, in the entire animal body, acts as an obftacle to the decifive difplay of the effects of galvanifm; and that,

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are produced in a limb without any apparent communication between the metals and the mufcles, except through the medium of a nerve, the communication is in fact completed by the moifture upon the furface of the nerve. In this cafe, the animal arc may be confidered as confifting of three pieces, difpofed in the following order; the nerve, the mufcle, and the water adhering to the furface of the nerve. The latter, indeed, ought rather to be confidered as a part of the excitatory arc. "When a nerve (fays Dr Fowler), which for fome time has been detached from furrounding parts, is either carefully wiped quite dry with a piece of fine muflin, or (left this fhould be thought to injure its ftructure) fuffered to remain fufpended till its moifture has evaporated, no contractions can be excited in the mufcles, to which it is diftributed, by touching it alone with any two metals in contact with each other; but if it be again moiftened with a few drops of water, contractions inftantly take place. And, in this way, by alternately drying and moiftening the nerve, contractions may at pleafure be alternately fufpended and renewed for a confiderable time. It may, indeed, be contended, that the moifture foftened, and thus reftored elafticity and free expanfion to the dried cellular membrane furrounding the fibres, of which the trunk of a nerve is compofed; and thus, by removing conftraint, gave free play to their organization.

"But from obferving, that in every other inftance where contractions are produced by the mutual contact of the metals, a conducting fubftance is interpofed between them and the mufcles as well as between them and the nerve; I think it would be unphilofophical not to allow, that, in the inftance in queftion, the moifture, adhering to the furface of the nerve, formed that requifite communication between the metals and the mufcles." We know of no accurate experiment by which it has ever been fhewn, that contractions can be produced in a limb without a communication being eftablifhed between the metals and nerve, and again between the mufcles and the metals, either directly, or through fome medium capable of conducting galvanifm.

To remove the only objection which can be made to Dr Fowler's experiment, and of which we have feen that he was himfelf aware, namely, that the nerve while dry is incapable of performing its functions, we repeated it in the following manner: A fmall, but vigorous and lively, male frog was decapitated, and the fciatic nerve being laid bare from the knee upwards, was cut through where it paffes out of the pelvis. Fifteen minutes after the head was cut off, the nerve having been cautioufly feparated from the furrounding parts, and coated with tinfoil in the ufual manner, a filver probe was applied to it and its coating, without any other communication with the mufcles, and ftrong 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 precifely in this fituation, one end of the probe being ftill in contact with the nerve and its coating, the other end was applied to the mufcles of the thigh, and the leg immediately contracted as ftrongly as ever. Upon moiftening 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 feveral times repeated with the utmoft care, and with the fame refult, that the dry nerve retained its functions completely. This appears to us perfectly decifive of the queftion.

that, though from its extreme tenuity, it may not altogether prevent these effects, yet it cannot but very materially diminish them.

10 Experiments on the excitatory 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.

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. 11 Inferences.

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

(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.

12 Experiments relating to circumstances different from the arcs.

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 phænomena 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 phænomena 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 commencement 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 ftate or pofition, fhould direct us in fubjecting every fuch animal only to experiments fuitable to its particular fusceptibility ; fhould enable us to eftimate, from the *efficacy* or *inefficacy* of our experiments, the galvanic value of the circumftances in which we every day find ourfelves, and fhould enable us to judge when the fuccefs or mifcarriage of an experiment can afford room for certain conclufions abfolutely negative or affirmative.

14 Experiments on the galvanic fufceptibility of animal bodies, &c.

IV. In their experiments upon *the means of varying, diminifhing, and renewing the fufceptibility of animal bodies* to the influence of galvanifm, the committee examined, 1ft, the influence of electricity upon that fufceptibility ; 2d, the effects of the mufcular organs, and of certain liquors, fuch as alcohol, the oxygenated muriatic acid, the folutions of potafh and opium, upon the galvanic properties ; 3d, and at the medical fchool of Paris they made a number of experiments, in order to afcertain what new modifications the galvanic energy undergoes in various cafes of fuffocation or afphyxia. Thefe laft-mentioned experiments were made upon hot-blooded animals, of which fome were reduced into the ftate of afphyxia by fubmerfion, fome by ftrangulation, fome by the action of gafes, while others were killed *in vacuo* by the difcharge of the electric fpark. In that fuffocation which was produced by fulphurated hydrogenous gas, by carbonic vapours, and by fubmerfion, in which the animal was fufpended by the hinder feet, the galvanic fufceptibility was entirely deftroyed. The galvanic fufceptibility was only fufpended by fuffocation produced by the pure carbonic acid confined under mercury. It was diminifhed, but not deftroyed, in thofe cafes of fuffocation, which were occafioned by fulphurated hydrogenous gas that had loft a portion of its fulphur, by gas ammoniac, gas azote, or fuch gafes as had been exhaufted of their pure air by refpiration ; and the fame thing was found to take place in animals which had perifhed by total fubmerfion. But the galvanic fufceptibility furvived unaltered in fuffocations brought on by fubmerfion in mercury, by pure hydrogenous gas, by carbonated hydrogenous gas, by oxygenated muriatic acid, by fulphureous acid ; as alfo when the fuffocation was occafioned by ftrangulation, by the abftraction of the air in the air-pump, or by difcharges from an electrical battery. The refults of the experiments at the medical fchool fuggefted the following reflections :

15 Reflections.

1. Though it be true that all cafes of fuffocation refemble one another in the privation of refpirable air, and in the fufpenfion of the functions of refpiration, and of the circulation of the blood ; yet, in their other circumftances, they are fubject to great differences, arifing from diverfity of nature in the fubftances by which they are occafioned.

2. Of thefe caufes, fome appear to act with a more thorough efficacy, penetrating at once all parts of the nervous and mufcular fyftems. Others again feem to act but fuperficially, producing only pulmonary afphyxia, with its immediate effects.

3. One of the moft remarkable changes not confined to the organs of refpiration, confifts in the alterations produced on the galvanic fufceptibility. In that refpect the various cafes of afphyxia differ greatly one from another.

4. The ftate of the irritability of the mufcles, when examined by means of bodies, the mechanical action of which caufes the mufcles to contract by irritating them, is far from always correfponding to the ftate of their galvanic fufceptibility.

5. Laftly, the caufes of fuffocation or afphyxia, do not act upon all parts of the mufcular fyftem in the fame manner ; but the heart is very often found in a ftate extremely different from that of the other mufcles.

16 Comparifon of the phenomena of galvanifm with thofe of electricity.

V. *The comparifon between the phenomena of galvanifm and thofe of electricity* is perhaps one of the moft interefting objects of attention in the whole body of animal phyfiology. It is well known that Galvani was accidentally led to his difcovery by obferving the motions of fome frogs, at a certain diftance from an electrical machine difcharging fparks. The committee from the inftitute made, therefore, fome attempts to afcertain the relations between electricity and galvanifm. Having firft paid due attention to the fufceptibility of animals toward the influence of electricity, they then fought to difcover to what precife degree animals divefted of the natural covering of the epidermis were liable to be affected by the variations of the electrical fluid in the atmofphere around them. Next, comparing the fufceptibility of electricity with the fufceptibility of galvanifm, they perceived that quantities of the electrical fluid, fuch as are ftill capable of being very accurately meafured by the electrometer, are, however, often too weak to act upon a frog that retains the moft perfect fenfibility to all the energy of galvanifm. The members of the committee purpofe to profecute farther their experiments upon this part of the fubject.

17 Refults of fome experiments by Humboldt.

VI. The following are the general refults of the experiments made by M. Humboldt in the prefence of the committee :

1. There is no truth in the affertion of certain phyfiologifts, that the experiments of galvanifm fail when tried upon the heart and thofe other mufcles of which the contractions depend not upon volition ; for thefe organs have been found to be actually fubject to the influence of galvanifm (D).

2. The effects of galvanifm are liable to be interrupted by the conftriction of a nerve, whenever both the nerve and the conftricting ligature are enveloped in the flefh of the animal body (E).

3. The powers of the exciting arc may be renovated or deftroyed, even though its fupporters remain the fame, and although the extremities of the arc be unchanged. Only the relations of the intermediate matters require to be altered.

4. There are atmofpheres of galvanifm.

5. There are fubftances which, though in an eminent manner conductors of electricity, yet interrupt the motions of galvanifm.

M. Humboldt had performed alfo other experiments which,

(D) This was demonftrated fix years ago by Dr Fowler.

(E) Dr Valli made this obfervation foon after the difcovery of galvanifm.

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.

18 Effects of galvanism upon some of the organs of sense.

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 Plaisers*, 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 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

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 irritation would produce, might not be attributed to the idioſyncriſis of the veſſels. This painful operation was ſcarcely commenced on the wound, by the application of zinc and ſilver, before the ſérous 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 Schalleru, 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. 19

Phenomena of galvaniſm ſuppoſed to reſult from electricity;

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:

20 This ſuppoſition ill founded.

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

21 Proofs by which Valli endeavours to ſupport it,

"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.

22 Inconcluſive and

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

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 experiments,

"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 incontestibly, 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. 24

And with the knowledge of electricity.

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.

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 Reafoning of Dr Wells on the fame fubject,

Wells, which is publifhed in the London Philofophical Tranfactions for 1795, that gentleman maintains the opinion, that the influence difcovered by Galvani is electrical. He admits, that it is not attended with thofe appearances of attraction and repulfion which are held to be the tefts of the prefence of electricity; but he contends, that "neither ought figns of attraction and repulfion to be in this cafe prefented on the fuppofition that the influence is electrical; fince it is neceffary, for the exhibition of fuch appearances, that bodies, after becoming electrical, fhould remain fo during fome fenfible portion of time; it being well known, for example, that the paffage of the charge of a Leyden phial, from one of its furfaces to the other, does not affect the moft delicate electrometer, fufpended from a wire, or other fubftance, which forms the communication between them."

26 Inconclufive likewife.

That the charge of a Leyden phial does not, in paffing 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 galvanifm in a ftate of reft in a body. If this influence ever exifts in fuch a ftate, we have no teft by which we can difcover its prefence; and it is only from the effects which it produces *in tranfitu* that we know of its exiftence. But the electric fluid, in paffing from link to link of a chain, fenfibly affects an electrometer; and in Dr Fowler's experiment with the fkate, for example, as more than one piece of metal is employed as an exciter, the fluid, in paffing from one piece to another, fhould have affected the light fubftances which were placed upon them. This appears to us a fufficient anfwer to the objection ftarted by Dr Wells: but the fame objection having been lately made to us by a gentleman from whom we fhall always receive every fuggeftion with uncommon deference, we thought it worth while to try the following experiment:

Three hours after a frog had been decapitated, it fhewed ftrong figns of galvanic fufceptibility. One of the fciatic nerves being coated with tinfoil in the ufual manner, the leg was laid upon a plate of zinc. A gentleman was defired to lay hold of the nerve and its coating with the fingers of one hand, which had been previoufly dipped in water, while with the other hand, alfo wet, he held the end of a fmall brafs chain about two inches in length. Another gentleman now took hold of the other end of the chain, and, with a filver probe, held in his other hand, touched the plate of zinc. The influence being thus made to pafs through the chain, the leg contracted vigoroufly; but a very fenfible electrometer, held fo near to the chain as almoft to touch it, was neither attracted nor repelled. In performing this experiment, it was neceffary to have the hands wet, as the dry cuticle tends much to obftruct the paffage of galvanifm; but the utmoft care was taken that the chain fhould be perfectly dry, otherwife the influence might have been tranfmitted by the moifture upon its furface without paffing through the chain itfelf.

To avoid the poffibility 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 filver. A gentleman now took a filver probe, and one end of the brafs 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 filver plate with the rod of filver, and the zinc plate with the rod of zinc. As the influence was not now to be made to pafs through his body, there was no neceffity for his hands being wet; the whole excitatory arc was therefore made completely dry. In this way very ftrong contractions were excited in the leg, and ftill the electrometer was not affected in the fmalleft degree when brought near the chain.

It is proper to obferve, that Dr Valli, in his affertion that attraction is a property of galvanifm, does not reft entirely upon his own obfervation: a committee of the Academy of Sciences at Paris performed the following experiment along with him: "They placed a prepared frog in a veffel which contained the electrometer of M. Coulomb, charged negatively and pofitively by turns. In both cafes, 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 fo much electricity as to affect the electrometer. The firft time we tried the experiment abovementioned with the brafs chain, we were almoft mifled by a fimilar circumftance. Inftead of an artificial electrometer, which we happened not to have at hand, we made ufe of a very long and flender human hair; and we found that it was ftrongly attracted by the chain. Upon an attentive examination, however, we found that this did not arife from the action of the influence paffing thro' the chain, but from the ftate of the hair itfelf, which was fo highly electrical as to be ftrongly attracted by every conducting fubftance which it approached. Upon fubftituting another hair, which fhewed no mark of being either pofitively or negatively electrified, it was neither attracted nor repelled by the chain. From the above, or fome fimilar circumftance, it is probable that Dr Valli's miftake has originated; but we are confident, that whoever will repeat the experiment with fufficient attention, will find the refult precifely as we have defcribed it.

Perhaps it may ftill be faid, that although we have never been able to difcover attraction and repulfion as properties of galvanifm, this may arife from our not being able to accumulate this influence in fufficient quantity. To this reafoning, if reafoning it can be called, we oppofe the following confiderations, which ftate a diffimilarity in the phenomena of electricity and galvanifm, that feems abfolutely irreconcileable with the identity of the caufe. 27

27 Demonftration, that the phenomena of galvanifm and of electricity refult not from the fame caufe.

Nothing is more completely eftablifhed in the fcience of electricity than this, that all thofe appearances which we call *attractions, repulfions, abftractions, and accumulation of electric fluid*, are precifely fimilar to what would be the appearances, if electricity were a fluid, whofe particles repel each other, and attract the particles of other matter, according to a certain law (See Electricity, *Suppl.*). Of all thofe phenomena, the moft remarkable is the accumulation of electric energy (to give it no more definite name), by means of thin idioelectrics, coated with non-electrics; fuch, namely, as are exhibited by the Leyden phial, the condenfer, the doubler, &c.

If the phenomena of galvanifm are produced by the paffage of electric fluid from one extremity of the excitatory arc to the other, this paffage will be regulated by the known laws of electricity. It may therefore be accumulated

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 $\frac{31}{1000}$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 accumulation 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 $\frac{47}{1000}$ or $\frac{50}{1000}$ of an inch thick, took a charge, although a cut of $\frac{31}{1000}$ 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 (H).

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. 28

Farther considerations on electricity and galvanism.

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 (I) ; whether, by

(H) What if it were called *metallorgasm*, which translates exactly metallic irritation, or metallegersism, from μεταλλον, and εγερσις *excitatio*.

(I) 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 incontestibly 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 retaining 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.

29 Difference in their mode of excitement,

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 (K). 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.

30 And in the duration of their effects.

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 sensation

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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.

(K) 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.

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 heighened 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. 31 Some men non-conductors of galvaniſm.

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 contary, when merely tranſmitted through the body in this manner, gives no ſhock, nor any ſenſation whatever, inſomuch 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 aud 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

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 ingenuity 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.

33 Dr Fowler heſitates on this point,

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

preventing the excitement or tranfmiffion of galvanifm. Befides, though we cannot prevent an involuntary contraction of our mufcles from taking place when an electric fhock of confiderable ftrength is paffed through them, yet any man may with his hand draw fparks from the prime conductor of an electric machine without fhrinking, though even thefe fparks would, if he were off his guard, produce a convulfive ftart.

34 We think without reafon.

If the galvanic influence exifted ready formed in the mufcles or nerves of animals, the only thing requifite to the production of the contractions would be to make a communication between the nerves and mufcles, by means of any fingle fubftance capable of conducting this influence; as water, for example: but the reverfe is known to be true. It may be faid, however, that, although there is no proof that any influence naturally refides in the nerves or mufcles capable of producing the effects mentioned by M. Galvani, thefe fubftances may ftill, by fome power, independent of the properties they poffefs in common with dead matter, *contribute* to the excitement of the influence, which is fo well known to exift in them after a certain application of metals. Upon this part of the fubject, the obfervations of Dr Wells will be found to merit confiderable attention.

"It is known (fays that gentleman), that if a mufcle and its nerve be covered with two pieces of the fame metal, no motion will take place upon connecting thofe pieces by means of one or more different metals. After making this experiment one day, I accidentally applied the metal I had ufed as the connector, and which I ftill held in one hand, to the coating of the mufcle only, while with the other hand I touched the fimilar coating of the nerve, and was furprifed to find that the mufcle was immediately thrown into contraction. Having produced motions in this way fufficiently often to place the fact beyond doubt, I next began to confider its relations to other facts formerly known. I very foon perceived, that the immediate exciting caufe of thefe motions could not be derived from the action of the metals upon the mufcle and nerve to which they were applied; otherwife it muft 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 cafe. The only fource, therefore, to which it could poffibly be referred, was the action of the metals upon my own body. It then occurred to me, that a proper opportunity now offered itfelf of determining whether animals contribute to the production of this influence by means of any other property than their moifture. With this view I employed various moift fubftances, in which there could be no fufpicion of life to conftitute, with one or more metals, different from that of the coatings of the mufcle and nerve, a connecting medium between thefe coatings, and found that they produced the fame effect as my body. A fingle drop of water was even fufficient for this purpofe; though, in general, the greater the quantity of the moifture which was ufed, the more readily and powerfully were contractions of the mufcle excited. But if the mutual operation of metals and moifture be fully adequate to the excitement of an influence capable of occafioning mufcles to contract, it follows, as an immediate confequence, that animals act by their moifture alone in giving origin to the fame influence in M. Galvani's experiments, unlefs we are to admit more caufes of an effect than what are fufficient for its production." We do not quote the above reafoning as perfectly conclufive, for it by no means appears to us to be fo; but it certainly gives fome probability to the opinion, that galvanifm is, as M. Volta fuppofes, the refult 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 fecond clafs, (that is, moifture, for all the conductors of the fecond clafs contain water), and that the bodies of animals act merely as moifture.

One of M. Humboldt's experiments related above, appears to us to ftrengthen the conclufion, that the influence difcovered by Galvani is fomething perfectly foreign to the bodies of animals. Can it be fuppofed that any fubftance which naturally refides in our bodies, fhould, in a few feconds after it is put in motion, convert the fimple ferous difcharge of a blifter into a dark coloured fluid, of a nature fo acrid as to irritate and violently inflame the fkin wherever it touches it? We do not fay that this is impoffible, for we are too little acquainted with the laws of fecretion to fay with certainty what may, or what may not, produce fuch a change; but we know no fimilar alteration produced, *in a few feconds*, by a mere change of action in the veffels themfelves.

We fhall not undertake to determine the nature of the caufe which produces fuch aftonifhing effects. We think it is certainly not the electric fluid, and probably fomething which refides or is formed in the excitatory arc; but we confider our knowledge of galvanifm as ftill in its infancy, and our ftock of facts as infinitely too fmall to admit of our forming a juft theory on the fubject. Fortunately, however, the difcovery of Galvani has attracted fo much the attention of philofophers 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 diftant, when thefe may be fo claffed, as to entitle the fubject to be ranked among the fciences. See Torpedo in this *Suppl.* 35 The caufe which produces the galvanic effects unknown.

While this article was in the prefs, we were favoured by a friend with an account of fome German differtations on the fubject, which we are obliged to infert in this irregular manner.

Mr Creve, furgeon in Wurtzburg, had an opportunity of obferving the galvanic irritation on the leg of a boy, which had been amputated far above the knee in the hofpital of that city. Immediately after the amputation, Mr Creve laid bare the crural nerve (kniekehlnerven), and furrounded it with a flip of tinfoil. He touched at once the tinfoil and the nerve with a French crownpiece. In that inftant the moft violent convulfions 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 thefe motions were made with much force and rapidity. None were produced when the tinfoil was taken away, or when a fteel pincer was ufed in place of a piece of filver, or when the tin or filver was covered with blood: but they were renewed ed when these obstacles were removed. These phenomena continued till 38 minutes after the amputation, when the limb became cold.

Dr Christopher Heinrich Pfaff (*in Dissertatione de Electricitate Animali*, 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 lumbal 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, *Farther 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, or GUARD DU CORD, in a watch, is that which ſtops the fuſee when wound up, and for that end is driven up by the ſpring. Some call it Guard-cock; others Guard du Gut.

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 paſſing through the uſual courſe of liberal education at the ſchool and the univerſity, he betook himſelf to the ſtudy of law for his profeſſion. In the year 1744 he was admitted a member of the Faculty of Advocates, and called to the Scottiſh bar.

In his practice as an advocate he ſoon began to be diſtinguiſhed, by a ſtrong, native rectitude of underſtanding; by that vivacity of apprehenſion and imagination which is commonly denominated *Genius;* by manly candour in argument, often more perſuaſive than ſubtlety and ſophiſtical artifice; by powers which, with diligence, might eaſily attain to the higheſt eminence of the profeſſion. But the ſame ſtrength, openneſs, and ardour of mind, which diſtinguiſhed him ſo advantageouſly among the pleaders at the bar, tended to give him a fondneſs for the gay enjoyments of convivial intercourſe, which was unfavourable to his progreſs in juridical erudition. Shining in the ſocial and convivial circle, he became leſs ſolicitouſly ambitious than he might otherwiſe have been, of the character of an eloquent advocate, or of a profound and learned lawyer. The vivacity of his genius was averſe from auſtere and plodding ſtudy, while it was captivated by the faſcinations of polite learning and of the fine arts. Nor did he always eſcape thoſe exceſſes in the purſuit of pleaſure into which the temptations of opening life are apt occaſionally to ſeduce the moſt liberal and ingenuous youth. But his cheerful conviviality, his wit, humour, taſte, 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 Seſſion and Juſticiary, the ſupreme judicature, civil and criminal, for Scotland. His place in the Court of Seſſion he continued to occupy till his death; but had, ſome years before, reſigned the office of a Commiſſioner of Juſticiary, and in recompence got a penſion of 200l. per annum. Clear diſcernment, ſtrong good ſenſe, conſcientious honeſty, and amiable benevolence, remarkably diſtinguiſhed all his opinions and conduct as a judge.

We not unfrequently ſee the gay young men of the preſent age, to turn, as they advance towards middle life, from the headlong purſuit of pleaſure to a ſordid and contracted ſelfiſhneſs, which excludes even thoſe few good qualities that ſeemed to accompany their firſt thoughtleſs days. Their life is divided between ſenſuality and that anxious *inhumane* avarice and ambition whoſe ultimate object is, to provide gratifications to ſenſuality and pride. The kindling light of rectitude, and the firſt ſparks of generous humanity, are extinguiſhed in their breaſts as ſoon as thoſe ebullitions of youthful paſſion and inexperience are over, by which the uſeful efficiency of their early good qualities was prevented. Hardly have they become tolerably well acquainted with mankind, when the milk of human kindneſs is turned into gall and venom in their hearts.

It was far otherwiſe with Lord Gardenſtone. As he advanced in years, humanity, taſte, public ſpirit, became ſtill more and more eminently the predominant principles in his mind.—He pitied the condition of the peaſantry, depreſſed rather by their ignorance of the moſt ſkilful modes of labour, and by their remoteneſs from the ſphere 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 promiſed a feaſible amelioration of public economy, and the principles of government.

In the year 1762 he purchaſed the eſtate of Johnſton, in the county of Kincardine. Within a few years after he began to attempt a plan of the moſt liberal improvement of the value of this eſtate, by an extenſion of the village of Laurencekirk, adjoining. He offered leaſes of ſmall farms, and of ground for building upon, which were to laſt for the term of one hundred years; and of which the conditions were extremely inviting to the labourers and tradeſmen of the ſurrounding country. Theſe offers were eagerly liſtened to. More deſirous to make the attempt beneficial to the country than to derive profit from it to himſelf, he was induced, within a few years, to reduce his ground-rents to one-half of the original rate.—Weavers, joiners, ſhoemakers, and other artiſans in a conſiderable number, reſorted to ſettle in the riſing village. His Lordſhip's earneſtneſs for the ſucceſs of his project, and to promote the proſperity of the good people whom he had received under his protection, led him to engage in ſeveral undertakings; by the failure of which he incurred conſiderable loſſes. Projects of a printfield, and of manufactures of linen and of ſtockings, attempted with ſanguine hopes in the new village, and chiefly at his Lordſhip's riſk and expence, miſgave in ſuch a manner as might well have finally diſguſted a man of leſs ſteady and ardent philanthropy with every ſuch engagement. But the village ſtill continued to advance. It grew up under his Lordſhip'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 magiſtracy, an annual fair, and a weekly market. He provived in it a good inn for the reception of travellers; and with an uncommon attention to the entertainment of the gueſts who might reſort to it, furniſhed this inn with a library of books for their amuſement. He invited an artiſt for drawing, from the continent, to ſettle at Laurencekirk. He had the pleaſure of ſeeing a conſiderable linen manufacture at length fixed in it. A bleachfield was alſo eſtabliſhed as a natural counterpart to the linen manufacture. Before his Lordſhip's death, he ſaw his plan of improving the condition of the labourers, by the formation of a new village at Laurencekirk, crowned with ſucceſs beyond his moſt ſanguine hopes. He has acknowledged, with an amiable frankneſs, in a memoir concerning this village, "That he had tried, in ſome meaſure, a variety of the pleaſures which mankind purſue; but never reliſhed any ſo much as the pleaſure ariſing from the progreſs of his village."

In the year 1785, upon the death of his elder brother, 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 deely 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 Edinbugh, 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

worthy of his regard; and that his attachment to liberty made him form expectations from the French revolution, which even the events which he faw ought to have repreffed. But his mind was by that time weakened by difeafe; and it would be very unjuft to balance the imprudencies of one or two years againft the meritorious actions of a whole life. Befides his travelling memorandums and his poems, his Lordfhip publifhed *A Letter to the Inhabitants of Laurencekirk*, the moft valuable, in our opinion, of all his publications; for it contains perhaps the moft falutary 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 thefe advices, it would give us pleafure to learn on good authority.

GAS. See that article, *Encycl.* and CHEMISTRY-*Index* in this *Supplement*. We have introduced the word here, to notice fome experiments made by Profeffor Jacquin of Vienna, at the defire of Dr Chladni, on the different gafes as the vehicle of founds. A glafs bell was furnifhed with a metallic ftopper cemented to a neck at the top; and in the bore of this cock, within the glafs, a fmall flute or pewter (etain) about fix inches in length was fixed. The glafs being then placed on the fhelf of the pneumatic veffel, and filled with any particular kind of gas, a bladder alfo filled with the fame gas, and provided with a cock, was adapted to the external aperture of the cock belonging to the bell-glafs. In this difpofition of the apparatus, the flute was made to found by gently preffing the bladder. Comparative experiments were made with atmofpheric air, oxygen, hydrogen, carbonic acid, and nitrous gas. The intenfity of the found did not vary; but when compared with that produced by atmofpheric air, the oxygen gas gave a found half a tone lower; azotic gas, prepared by different methods, conftantly gave a found half a tone lower; hydrogen gas gave nine or eleven tones higher; carbonic acid gas gave one-third lower, and nitrous gas alfo very nearly a third lower. A mixture of oxygen gas and azot, in the proportions of the atmofpheric air, afforded the tone of this laft; that is to fay, it was half a tone higher than each of the component parts alone. When the two gafes were not uniformly mixed, the found was abominably harfh. Chladni intends to give a fuller account of thefe interefting experiments.—*Journal de Phyfique*, Vol. IV. N. S. p. 57.

GAZONS, in fortification, turfs, or pieces of frefh earth covered with grafs, cut in form of a wedge, about a foot long, and half a foot thick, to line or face the outfide 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, feen from the earth, is referred.

Geocentric Latitude of a Planet, is its latitude as feen 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 faid 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 diftance meafured on the ecliptic, in the order of the figns, between the geocentric place and the firft point of Aries.

GEOMETRICAL METHOD OF THE ANCIENTS. The ancients eftablifhed the higher parts of their geometry on the fame principles as the elements of that fcience, by demonftrations of the fame kind: and they were careful not to fuppofe any thing done, till by a previous problem they had fhewn that it could be done by actually performing it. Much lefs did they fuppofe any thing to be done that cannot be conceived; fuch as a line or feries to be actually continued to infinity, or a magnitude diminifhed till it become infinitely lefs than what it is. The elements into which they refolved magnitudes were finite, and fuch 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 myfteries.

Geometrical Solution of a problem, is when the problem is directly refolved according to the ftrict rules and principles of geometry, and by lines that are truly geometrical. This expreffion is ufed in contradiftinction to an arithmetical, or a mechanical, or inftrumental folution, the problem being refolved only by a ruler and compaffes.

The fame term is likewife ufed in oppofition to all indirect and inadequate kinds of folutions, as by approximation, infinite feries, &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 feries, &c.

GEORGIUM SIDUS (fee ASTRONOMY-*Index*, *Encycl.*) has no fewer than fix fatellites revolving round it, all difcovered by Dr Herfchel. Of the two which he firft difcovered, one was found to revolve in 8 days 17 h. 1 m. 17 fec. at the diftance of 33″ from its primary; and the other in 13 d. 11 h. 5 m. 1,5 fec. at the diftance of 44″,23. The planes of their orbits form fuch large angles with that of the planet itfelf, and confequently of the ecliptic, as to be almoft perpendicular to it. To this remarkable departure from the analogy of the old planets, another ftill more fingular has been lately announced. They move in a retrograde direction! The new fatellites revolve as follows, the periodical times being inferred from their greateft elongations: The interior fatellite in 5 d. 21 h. 25 m. at the diftance of 25″,5. A fatellite intermediate between the two old ones in 10 d. 23 h. 4 m. at the diftance of 38″,57. The neareft exterior fatellite at about double the diftance of the fartheft old one, and confequently its periodical time 38 d. 1 h. 49 m. And the moft diftant fatellite full four times as far from its primary as the old fecond fatellite. Whence it will take at leaft 107 d. 16 h. 40 m. to complete its revolution. Whether the motions of thefe four be direct or retrograde, is, we fuppofe, not yet determined.

From fome obfervations of the Doctor, with an excellent feven-feet telefcope, certain appearances, refembling that of two rings furrounding the planet, and croffing each other at right angles, were feen on feveral different days. They were not altered in pofition by turning the fpeculum in its cell; but (fays Mr Nicholfon) there is little doubt that they were optical deceptions, becaufe they kept their pofition with refpect to the tube, after the relative pofition 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. Gerard.

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

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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 disjoined 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 lie

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* 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 Lumiſden. 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 ſchirrous 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.

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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.

* *Dr Beattie.*

The fruits of this inceſſant ſtudy were, beſides the lectures which he read to his different claſſes, 1*ſt*, *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. 4*th*, Two volumes of *Sermons*; of which the firſt was publiſhed in 1780, and the ſecond in 1782. 5*th*, 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.

† *The Rev. Skene Ogilvie, Old Aberdeen.*

"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, preſerved 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 thro' 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 expence 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 prelections 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 ordinary

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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, inconteſtibly 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 ſpeculation, 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, 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 oxigenated 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 oxigenated 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 Uſlar's Fragments of Phytology, Plenck's Phyſiology, Villdenow's Dendrology, and *Dictionnaire de Phyſique* par Gehler.

(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 Pfaſs 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.

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 cytisus or pigeon pea (*cytisus cajan*), the *dodonea angustifolia*, the climbing mimosa (*mimosa 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 oxigenated 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 oxigenated 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 Caffres, or at least from the Briquas and Bremas, whom they consider as tribes of Caffres.

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 Gheyssiquas do not differ from the surrounding nations, except in having adopted a particular colour for their ornaments. All the ornaments of the Gheyssiquas 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 Gheyssiquas, 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 Gheyssiquas 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 Loangoes, Pomboes, and Cormantins, marks of distinction

Ghirgong. tion more eafily difcerned. Be this as it may, the operation among the Gheyffiquas is performed by the father, commonly at the birth of the child, though fometimes not till he has completed his third year.

GHIRGONG, the capital of *Afam* in Hindoftan, is, according to Mr Pennant, fituated in latitude 26° 30′ north. He does not ftate its longitude. It has four gates, and the city is encompaffed with a bound hedge of bamboos. The Rajah's palace is furrounded by a caufey, planted on each fide with a clofe hedge of bamboos, which ferves inftead of a wall. On the outfide there is a ditch, which is always full of water. The Rajah's feat is adorned with lattice work and carving. Within and without have been placed plates of brafs, fo well polifhed, that when the rays of the fun ftrike upon them they fhine like mirrors. It is an afcertained fact, that 3000 carpenters and 12,000 labourers were conftantly employed in this work during two years before it was finifhed.

Pennant's View of Hindoftan.

The Afiatic Refearches fpeak much of the wealth of Afam, 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 wafhing the fand of the rivers, and is one of the fources of revenue; 12,000, fome fay 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 filk.

Among the fruits which this country produces are mangoes, plantains, jacks, oranges, citrons, limes, pine apples, and puniala, a fpecies of tamarind, which has fuch an excellent flavour, that every perfon who taftes it prefers it to the plum. There are alfo cocoa nut trees, pepper vines, and areca trees. The fugar cane excels in foftnefs and fweetnefs, and is of three colours, red, black, and white. There is ginger free from fibres, and betel vines. The ftrength of vegetation and fertility of the foil are fuch, that whatever feed is fown or flips planted they always thrive. The environs of Ghirgong furnifh fmall apricots, yams, and pomegranates; but as thefe articles are wild, and not affifted by cultivation and engraftment, they are very indifferent. The principal crop in this country confifts in rice and lentiles. Wheat and barley are never fown; lignum aloes is alfo a production of this country. The filks are excellent, and refemble thofe of China, but they manufacture very few more than are required for ufe. They are fuccefsful in embroidering with flowers and in weaving velvet.—One of their great forefts 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 horfes, camels, nor affes, fuch as are brought from other countries.

According to our author, "the people of Afam are a bafe unprincipled nation, and have no fixed religion. They follow no rule but that of their own inclination, and make their own vicious minds the teft of the propriety of their actions. They do not adopt any mode of worfhip practifed either by heathens or Mahomedans, nor do they concur with any of the known fects which prevail among mankind; unlike the pagans of Hindoftan, they do not reject victuals which have been dreffed by Moflems, and they abftain from no flefh except human. They even eat animals that have died a natural death."

On this paffage, one of the ableft of our literary journalifts obferves, that in juftice to the people of Afam, we muft remark, that the above account, extracted from the memoirs of Mir Jumla's expedition into that country, was compofed by a rigid Mahomedan, at the court of that fanatical tyrant Aurengzebe. The author and his mafter faw, in the Afamefe, only idolaters; and, in idolaters, the meaneft of mankind. Their diet, though lefs reftricted than that of the Hindoos of Bengal, is by no means promifcuous; and their religion does not in any way differ from that of Hindoftan,—as might eafily be proved by their coins, infcribed with the names of Hindoo deities.

Gibbon.

GIBBON (Edward, Efq.), the celebrated hiftorian 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 firft child of the marriage of Edward Gibbon, Efq; and Judith Porten, the youngeft 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 poffeffed lands in the hundred and parifh of Rolvenden, in the diftrict which is now called the *Weald* of Kent. In that diftrict the elder branch of the family ftill adheres to its native foil, without much increafe or diminution of property; but the fortunes of the younger branch, from which fprung the fubject of this memoir, were fluctuating. It is not, however, with his family, but with himfelf, that we are concerned.

So feeble was his conftitution, and fo precarious his life during his childifh years, that at the baptifm of each of his brothers (and they were five in number) his father's prudence fucceffively repeated the name of Edward, that, in cafe of the death of the eldeft fon, this patronymick appellation might ftill be perpetuated in the family. His brothers and a fifter were all fnatched away in their infancy; and, in terms of affectionate gratitude, he attributes his own prefervation to the more than maternal care of a maiden aunt, his mother's eldeft fifter. "Many anxious and folitary days (fays he) did that dear and excellent woman confume in the patient trial of every mode of relief and amufement. Many wakeful nights did fhe fit by my bed-fide in trembling expectation that each hour would be my laft. Suffice it to fay, that while every practitioner from Sloane and Ward to the Chevalier Taylor was fucceffively fummoned to torture or relieve me, the care of my mind was too frequently neglected for that of my health. Compaffion always fuggefted an excufe for the indulgence of the mafter, or the idlenefs of the pupil; and the chain of my education was broken as often as I was called from the fchool of learning to the bed of ficknefs."

His education feems indeed to have been far from fyftematical. At the age of feven he was delivered into the hands of Mr John Kirby, who exercifed about eighteen months the office of his domeftic tutor, and of whom he writes in terms of refpect. This man had been an indigent curate in Cumberland, and when forced by diftrefs 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 leaft a temporary fhelter, had not an act of indifcretion again driven him into the world. One day reading prayers in the parifh church, he moft unluckily forgot the name of

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 diſmiſſion 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 audacioſly 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 fifteenth 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."

Thus 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 ſally 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."

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 contemptuously applied to the successors of Lipsius and Casaubon; and I was provoked to hear *, that the exercise of the memory, their sole merit, had been superseded by the nobler faculties of the imagination and the judgment

* *See Le Discours Preliminaire par D'Alembert à l'Encyclopédie.*

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 exercifed and difplayed by the ftudy of ancient literature." This laudable ambition continued; and in his father's houfe at Beriton in Hampfhire he finifhed his *Effai fur l' Etude de la Literature;* which, after being revifed by Mallet the poet and Dr Maty of the Britifh mufeum, was, in 1761, publifhed in a fmall 12mo volume.

The fubjects of tafte, criticifm, and philofophy, which in this work came under our young author's confideration, could hardly promife much novelty of remark. Some former obfervations, however, he appears to have placed in a new and pleafing point of view; advancing, moreover, fome ingenious conjectures, and difplaying no inconfiderable erudition. Yet, by his own account, he was at this time almoft a ftranger to the writers of Greece; and when he quotes them, it is probable that the quotations are given at fecond hand. To this effay was prefixed a dedication to his father in the Englifh language, which exhibits the author himfelf in a very amiable light; but if his reputation had depended folely upon this youthful attempt, the name of Gibbon would have been loft in oblivion. Yet he feems, even in his riper years, to have been delighted with it himfelf, and to have confidered its merits as equal to thofe of his later productions; but Milton, it is faid, preferred the Paradife Regained to the Paradife Loft.

Before the publication of this effay, the author, at his own defire, had been appointed a captain in the South Hampfhire militia, in which he ferved upwards of two years. At firft, the company of ruftic and illiterate officers, and the buftle of a military life, were extremely difagreeable to him, as they interrupted his ftudies; but he admits, that his military fervices, his bloodlefs and inglorious campaigns, as he calls them, were, on the whole, beneficial, as they brought him acquainted with Englifh manners, Englifh parties, and Englifh principles, to which his foreign education and referved temper had hitherto kept him an entire ftranger. In the camp and in quarters he had even found leifure, after the firft feven or eight months of his fervice, to read a great deal of Greek, and to plan different hiftorical works, to the compofition of which he feems to have thought that he was born with an innate propenfity. He always talks of himfelf as a philofopher; but furely a more unphilofophical perfuafion than this has feldom 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 difbanding of the militia in which he had borne the commiffion of a captain. In that metropolis he ftaid not long. He vifited palaces, churches, gardens, and theatres, and was introduced to D'Alembert and Diderot, then confidered as at the head of French fcience. From Paris he proceeded to Switzerland, and once more took up his refidence at his favourite Laufanne. Voltaire's impieties had forced him from that town to his own caftle at Ferney, where our author once vifited him, without (he fays) courting his more intimate acquaintance.

The fociety in which Mr Gibbon moft delighted during his fecond refidence at Laufanne was a very fingular one. "It confifted of fifteen or twenty unmarried ladies of genteel families; the eldeft perhaps about twenty, all agreeable, feveral handfome, and two or three of exquifite beauty. At each other's houfes they affembled almoft every day, without the controul, or even the prefence of a mother or an aunt; they were trufted to their own prudence, among a crowd of young men of every nation in Europe. They laughed, they fung, they danced, they played at cards, they acted comedies; but in the midft of this carelefs gaiety, they refpected themfelves, and were refpected by the men; the invifible line between liberty and licentioufnefs was never tranfgreffed by a gefture, a word, or a look, and their virgin chaftity was never fullied by the breath of fcandal or fufpicion."

We readily agree with our author that this fingular inftitution was expreffive of the innocent fimplicity of Swifs manners; and we only regret that he had not the fame refpect for the ladies of his own country as for thofe frolic females of Switzerland. He would not, in that cafe, have ftained fome of his moft brilliant pages with obfcene ribaldry.

We fhall not follow him in his ramble through Italy, or repeat his remarks on the towns which he vifited. It is fufficient, in fuch a fketch as this, to inform our readers, that it was at Rome on the 15th of October 1764, as he fat mufing amidft the ruins of the Capitol, that the idea of his great work firft ftarted into his mind. But his original plan was circumfcribed to the decay of the city rather than of the empire.

From carrying even this contracted plan into execution he was for fome years diverted. On the 25th of June 1765 he arrived from Italy at his father's houfe in Hampfhire, and found that he had filial duties to perform which interrupted his ftudies and difturbed his quiet. His father had involved himfelf in difficulties from which he could be extricated only by felling or mortgaging part of his eftate; and to fuch fale or mortgage our author cheerfully confented. He regrets on this occafion that he had not "embraced the lucrative purfuits of the law or of trade, the chances of civil office or India adventure, or even the fat flumbers of the church;" and it is to be hoped that, when he thought even of *flumbering* in the church, he had ftill fome faith in revealed religion. He wafted fome time in planning a hiftory of the revolutions of Switzerland, and even wrote part of it in the French language, which, by the advice of friends, he however fuppreffed. We next find him engaged with a friend in a Journal entitled *Memoires Literaires de la Grande Bretagne*, of which two volumes for the years 1767 and 1768 were publifhed, and a third almoft completed, when his friend, a native of Switzerland, was engaged, through his intereft, as travelling governor to Sir Richard Worfley, and the Journal was, of courfe, abandoned. He then entered the lifts with Warburton; whofe interpretation of the fixth book of the Æneid he attacked with great petulance and with much fuccefs. The bifhop of Glocefter was by this time in a ftate of great mental decay, which was peculiarly unfortunate for our author; for had his Lordfhip enjoyed his priftine vigour, he would probably have given Mr Gibbon fuch a chaftifement as might have made him more modeft afterwards when writing the hiftory of the Decline and Fall of the Roman Empire.

To that great work he now fat down ferioufly; and the hiftory which he gives of his preparatory ftudies fufficiently

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 religon; 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 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, acknowledgd 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 Crœſus, 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 Crœſus, 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 Crœſus!'

(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.'

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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 downfal 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 Leman 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 inſtilling 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.

GIBRALTAR is a fortreſs of immenſe ſtrength, of which a very full account has been given in the *Encyclopædia.*

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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 Mortar, 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 face 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, incruſted 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 flimſy quilt-like cone, ſuſpended from the roof, to the robuſt trunk of a pillar, three feet in dimeter, 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 heterogenial 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. ftates, partially fcattered over the furface of the mountain. Thefe having been fwept, by heavy rains at different periods, from the furface into the fituations above defcribed, and having remained for a long feries of years in thofe places of reft, expofed to the permeating action of water, have become inveloped in, and cemented by, the calcareous matter which it depofits.

"The bones, in this compofition, have not the fmalleft appearance of being petrified; and if they have undergone any change, it is more like that of calcination than that of petrifaction, as the moft folid parts of them generally admit of being cut and fcraped down with the fame eafe as chalk,

"Bones combined in fuch concretions are not peculiar to Gibraltar: they are found in fuch large quantities in the country of Dalmatia, and upon its coafts in the iflands of Cherfo and Ofero, that fome naturalifts have been induced to go fo far as to affert, that there has been a regular ftratum of fuch matter in that country, and that its prefent broken and interrupted appearance has been caufed by earthquakes, or other convulfions, experienced in that part of the globe. But, of late years, a traveller (Abbé Alberto Fortis) has given a minute defcription of the concretion in which the bones are found in that country: And by his account it appears, that with regard to fituation, compofition, and colour, it is perfectly fimilar to that found at Gibraltar. By his defcription, it alfo appears that the two mountain rocks of Gibraltar and Dalmatia confift of the fame fpecies of calcareous ftone; from which it is to be prefumed, that the concretions in both have been formed in the fame manner and about the fame periods.

"Perhaps if the fiffures and caves of the rock of Dalmatia were ftill more minutely examined, their former communications with the furface might yet be traced, as in thofe defcribed above; and, in that cafe, there would be at leaft a ftrong probability, that the materials of the concretions of that country have been brought together by the fame accidental caufe which has probably collected thofe found in the caverns of Gibraltar. Major Imrie traced, in Gibraltar, this concretion, from the loweft part of a deep perpendicular fiffure, up to the furface of the mountain. As it approached to the furface, the concretion became lefs firmly combined, and, when it had no covering of the calcareous rock, a fmall degree of adhefion only remained, which was evidently produced by the argillaceous earth, in its compofition, having been moiftened by rain and baked by the fun.

"The depth at which thefe materials had been penetrated by that proportion of ftalactitical matter, capable of giving to the concretion its greateft adhefion and folidity, he found to vary according to its fituation, and to the quantity of matter to be combined. In fiffures, narrow and contracted, he found the concretion poffeffing a great degree of hardnefs at fix feet from the furface; but in other fituations more extended: and where a larger quantity of the materials had been accumulated, he found it had not gained its greateft degree of adhefion at double that depth. In one of the caves, where the mafs of concretion is of confiderable fize, he perceived it to be divided into different beds, each bed being covered with a cruft of the ftalactitical fpar, from one inch to an inch and a half in thicknefs; which feems to indicate, that the materials have been carried in at various periods, and that thofe periods have been very remote from each other.

Gibraltar.

"At Rofia Bay, upon the weft fide of Gibraltar, this concretion is found in what has evidently been a cavern, originally formed by huge unfhapely maffes of the rock which have tumbled in together. The fiffure, or cavern formed by the difruption and fubfidence of thofe maffes, has been entirely filled up with the concretion, and is now expofed to full view by the outward mafs having dropped down in confequence of the encroachments of the fea. It is to this fpot that ftrangers are generally led to examine the phenomenon; and the compofition, having here attained to its greateft degree of hardnefs and folidity, the hafty obferver, feeing the bones inclofed in what has fo little the appearance of having been a vacuity, examines no further, but immediately adopts the idea of their being incafed in the folid rock. The communication from this former chafm to the furface from which it has received the materials of the concretion, is ftill to be traced in the face of the rock, but its opening is at prefent covered by the bafe of the line wall of the garrifon. Here bones are found that are apparently human; and thofe of them that appear to be of the legs, arms, and vertebræ of the back, are fcattered among others of various kinds and fizes, even down to the fmalleft bones of fmall birds. Major Imrie found here the complete jaw-bone of a fheep; it contained its full complement of teeth, the enamel of which was perfect, and its whitenefs and luftre in no degree impaired. In the hollow parts of fome of the large bones was contained a minute cryftallization of pure and colourlefs calcareous fpar; but, in moft, the interior part confifted of a fparry cruft of a reddifh colour, fcarcely in any degree tranfparent.

"At the northern extremity of the mountain, the concretion is generally found in perpendicular fiffures. The miners there, employed upon the fortifications in excavating one of thofe fiffures, found, at a great depth from the furface, two fkulls, which were fuppofed to be human; but, to the Major, one of them, if not both, appeared to be too fmall for the human fpecies. The bone of each was perfectly firm and folid; from which it is to be prefumed, that they were in a ftate of maturity before they were inclofed in the concretion. Had they appertained to very young children, perhaps the bone would have been more porous, and of a lefs firm texture. The probability is, that they belonged to a fpecies of monkey, which ftill continues to inhabit, in confiderable numbers, thofe parts of the rock which are to us inacceffible.

"This concretion varies, in its compofition, according to the fituation in which it is found. At the extremity of Princes Lines, high in the rock which looks towards Spain, it is found to confift only of a reddifh calcareous earth, and the bones of fmall birds cemented thereby. The rock around this fpot is inhabited by a number of hawks, that, in the breeding feafon, neftle here and rear their young; the bones in this concretion are probably the remains of the food of thofe birds. At the bafe of the rock, below King's Lines, the concretion confifts of pebbles of the prevailing calcareous rock. In this concretion, at a very confiderable depth under the furface, was found the under parts of a glafs bottle, uncommonly fhaped, and of great thicknefs; the colour of the glafs was of a dark green."

Major

Major Imrie makes an apology for giving fo minute a defcription of thefe foffil bones ; but, in our opinion, the public is indebted to him for beftowing fo much attention on a fubject which all muft admit to be curious, and which, from the ftrange inferences drawn from fimilar phenomena by modern philofophers, has become important as well as curious.

We cannot difmifs this article without noticing the fubterraneous galleries conftructed in the rock not only for the protection of the men during a fiege, but alfo for placing cannon, to annoy the enemy, in fituations inacceffible but by fuch means. The idea of forming thefe galleries was conceived by the late Lord Heathfield when governor, and by him, in fome meafure, carried into execution ; though the plan was not completed till lately by General O'Hara. Of thefe galleries we have in the *Monthly Magazine* for April 1798 an animated account, which we fhall infert in the writer's own words.

"The fubterraneous galleries are very extenfive, pierce the rock in feveral places and in various directions, and at various degrees of elevation ; all of them have a communication with each other, either by flights of fteps cut in the rock, or by wooden ftairs where the paffages are required to be very perpendicular.

"The centinels may now be relieved during a fiege from one poft to another in perfect fafety ; whereas, previoufly to the conftructing of thefe galleries, a vaft number of men were killed by the Spaniards while marching to their feveral ftations. The width of thefe galleries is about twelve feet, their height about fourteen. The rock is broken through in various places, both for the purpofe of giving light and for placing the guns to bear on the enemy. In different parts there are fpacious receffes, capable of accommodating a confiderable number of men. To thefe receffes they give names, fuch as St Patrick's Chamber, St George's Hall, &c. The whole of thefe fingular ftructures have been formed out of the folid rock by blafting with gunpowder. Through the politenefs of an officer on duty, a place called Smart's Refervoir was opened for our infpection, which is a great curiofity, and not generally permitted to be fhewn. It is a fpring at a confiderable depth in the body of the rock, and is above 700 feet above the level of the fea ; we defcended into the cavern that contains it by a rope ladder, and with the aid of lighted candles proceeded through a narrow paffage over cryftallized protuberances of the rock till we came to a hollow, which appears to have been opened by fome convulfion of Nature. Here, from a bed of gems, arifes the falutary fount, clear as the brilliant of the eaft, and cold as the icicle. We hailed the nymph of the grot, and, proftrating ourfelves, quaffed hygean nectar from her fparry urn. When reftored to the light of day, we obtained, through the medium of the fame gentleman, the key of St George's Hall, at which we arrived by a very intricate and gloomy path to the fpacious excavation, which is upwards of an hundred feet in length, its height nearly the fame. It is formed in a femicircular part of the rock ; fpacious apertures are broken through, where cannons of a very large calibre command the ifthmus, the Spanifh lines, and a great part of the bay. The top of the rock is pierced through, fo as to introduce fufficient light to enable you to view every part of it. It appears almoft incredible that fo large an excavation could be formed by gunpowder, without blowing up the whole of that part of the rock, and ftill more fo, that they fhould be able to direct the operations of fuch an inftrument, fo as to render it fubfervient to the purpofe of elegance. We found in the hall a table, placed, I fuppofe, for the conveniency of thofe who are traverfing the rock. The cloth was fpread, the wine went round, and we made the vaulted roof refound with the accents of mirth and the fongs of conviviality."

Thefe excavations are indeed very extraordinary works ; but as the whole rock abounds with caverns, we wifh that our author had inquired more particularly than he feems to have done, whether St George's Hall be wholly the work of art. From one of the paffages which we have extracted from Major Imrie's memoir, we are led to think that it is not, or at leaft, that the concretion removed had not acquired the confiftence of the more folid parts of the rock. If this was the cafe, much of the wonder will vanifh, fince the pick-axe and chifel were probably employed to give elegance to the vault, and even, in fome degree, to direct the operation of the gunpowder.

GIMBOLS, are the brafs rings by which a fea-compafs is fufpended in its box that ufually ftands in the binacle.

GIRT, in timber-meafuring, is the circumference of a tree, though fome ufe this word for the quarter or 4th part of the circumference only, on account of the great ufe that is made of it ; for the fquare of this 4th part is efteemed and ufed as equal to the area of the fection of the tree ; which fquare therefore multiplied by the length of the tree, is accounted the folid content. This content, however, is always about one-fourth part lefs than the true quantity ; being nearly equal to what this will be after the tree is hewed fquare in the ufual way : fo that it feems intended to make an allowance for the fquaring of the tree.

Girt *Line*, is a line on the common or carpenter's fliding rule, employed in cafting up the contents of trees by means of their girt.

GLASS Etching, or *Engraving upon*, is in the article Chemistry (*Encycl.*) faid to be a new art ; and as that acid which diffolves filiceous earth, and alfo glafs, was firft difcovered in the year 1771 by Scheele, one might naturally imagine that the art of etching with it upon glafs could not be older. By many others, as well as by us, it has indeed been noticed as a new invention ; yet Profeffor Beckmann, whofe laborious refearches have brought many things to light, has proved, that fo early as the year 1670 the art of etching upon glafs was difcovered by Henry Schwanhard, fon of George Schwanhard, who was a celebrated glafs-cutter, patronized by the Emperor Ferdinand III. about the middle of the laft century. At the time of his death, 1667, the father practifed his art at Prague and Ratifbon. Whether the fon followed the fame bufinefs at the fame towns, or removed to Nuremberg, is not very evident from the profeffor's hiftory ; but in the year above-mentioned, fome *aqua regia (nitro muriatic acid)* having accidentally fallen on his fpectacles, he was furprifed to find the glafs corroded by it, and become quite foft. He thus found himfelf in poffeffion of a liquid by which he could etch writing and figures upon plates of glafs.

Such is our information ; but if it be admitted (and it would difplay unreafonable fcepticifm to queftion it), Schwanhard muft either have improved the nitro-muriatic acid

acid by fome means or other unknown to us, or have confined his etchings to fome particular kinds of glafs; for the *fluoric* is the only acid, with which we are acquainted, that corrodes all glafs. (See CHEMISTRY-*Index* in this *Supplement*). M. Beckmann indeed feems to think that he had difcovered the fluoric acid itfelf; 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 glafs.

"When the *fpiritus nitri per diftillationem* has paffed into the recipient, ply it with a ftrong fire, and when well dephlegmated, pour it, as it corrodes ordinary glafs, into a Weldenburg flafk. Then throw into it a pulverifed green Bohemian emerald, otherwife called *hefphorus* (which, when reduced to powder, and heated, emits in the dark a green light), and place it in warm fand for 24 hours. Take a piece of glafs well cleaned, and freed from all greafe 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 ftand fo much the better; and at the end of fome time the glafs will be corroded, and the figures which have been traced out with fulphur and varnifh will appear as if raifed above the pane of glafs."

That the Bohemian emerald or *hefphorus* mentioned in this receipt is green fparry fluor, cannot, fays the profeffor, be doubted; and he feems to have as little doubt of the receipt itfelf having paffed from Schwanhard and his fcholars to the periodical work of 1725, from which it has been lately inferted in the Œkonomifche Encyclopedie of Krunitz. This fuppofition certainly acquires a confiderable degree of probability from the fimilarity of Schwanhard's method of etching to that which is here recommended, and which is fo different from what is now followed. At prefent, the glafs is covered with a varnifh either of ifinglafs diffolved 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 varnifh, and then by his liquid corroded the glafs around them. His figures, therefore, when the varnifh was removed, remained fmooth and clear, appearing raifed from a dim or dark ground; and M. Beckmann, who perfuaded fome ingenious artifts to make trial of this antient method of etching, declares, that fuch figures have a much better effect than thofe which are cut into the glafs.

Before concluding this article, it may be worth while juft to mention a propofal which has been lately made to employ glafs inftead of copper for throwing off prints in the rolling prefs. That it is poffible to ufe glafs plates of great thicknefs for this purpofe, it would be rafh to deny; but the fuperiority of fuch plates to thofe of copper we cannot conceive. If not broken in pieces in the rolling prefs, they would doubtlefs laft longer; but the expence of them at firft would probably be greater, and the engraving on them could not be fo fine.

GLOSSOCOMMON, in mechanics, is a name given by Heron to a machine compofed of divers dented wheels with pinions, ferving to raife huge weights.

GLUCINA (A), a peculiar earth difcovered by Vauquelin in the beryl and the emerald. Its general properties are as follows: 1. It is white; 2. Infipid; 3. Infoluble in water; 4. Adhefive to the tongue; 5. Infufible; 6. Soluble in the fixed alkalis; 7. Infoluble in ammoniac; 8. Soluble in the carbonat of ammoniac; 9. Soluble in almoft every one of the acids (except the carbonic and phofphoric acids), and forming falts of a faccharine tafte; 10. Fufible with borax into a tranfparent glafs; 11. Abforbs one fourth of its weight of carbonic acid; 12. Decompofes the aluminous falts; 13. Is not precipitable by well faturated hydro-fulphurets.

The fpecific characters of glucina, which are united in none of the other known earths, are: 1. Its falts are faccharine, and flightly aftringent; 2. It is very foluble in the fulphuric acid by excefs; 3. It decompofes the aluminous falts; 4. It is foluble in the carbonat of ammoniac; 5. Is completely precipitated from its folutions by ammoniac; 6. Its affinity for the acids is intermediate between magnefia and alumine.

One hundred parts of beryl contain 16 of glucina; but for the beft method of analyzing the beryl, and of courfe obtaining the earth, we muft refer our readers to the article MINERALOGY in this *Supplement*; and fhall conclude this fhort article with a valuable and judicious remark of Vauquelin's.

"It almoft always happens (fays this able chemift), in the fciences of obfervation, and even in the fpeculative fciences, that a body, a principle, or a property, formerly unknown, though it may often have been ufed, or even held in the hands, and referred to other fimple fpecies, may, when once difcovered, be afterwards found in a great variety of fituations, and be applied to many ufeful purpofes. Chemiftry affords many recent examples of this truth. Klaproth had no fooner difcovered the different fubftances with which he has enriched the fcience, but they were found in various other bodies; and if I may refer to my own proceffes, it will be feen, that after I had determined the characters of chrome, firft found in the native red lead, I eafily recognized it in the emerald and the ruby. The fame has happened with regard to the earth of the beryl. I have likewife detected it in the emerald; in which, neverthelefs, it was overlooked both by Klaproth and myfelf in our firft analyfis: fo difficult it is to be aware of the prefence of a new fubftance, particularly when it poffeffes fome properties refembling thofe already known!"

GOLD, the moft perfect of all the metals. See CHEMISTRY-*Index* in this *Supplement*.

It has been a very common opinion among metallurgifts, that tin has the property of deftroying the ductility of gold, on being melted with it even in very fmall quantities; and Dr Lewis adds, that even the vapours which arife from tin in the fire, make gold fo brittle, that it flies in pieces under the hammer. This opinion was controverted by Stanefby Alchorne, Efq; of his Majefty's mint, who made a fet of experiments, which, in his opinion, authorife a very different conclufion, 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 moft characteriftic property being that it forms falts of a faccharine tafte, they gave it a name derived from γλυκαινω, *to render fweet*. According to this etymology, fhould not the name be *Glycina*?

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will contaminate gold in proportion to the quantity mixed with it, yet there does not appear in tin any thing fpecifically inimical to that precious metal.

As we have elfewhere (fee CHEMISTRY, nº 1091, &c. *Encycl.*) enumerated thefe experiments, and admitted the conclufion drawn from them, it becomes our duty, in this place, to ftate what has been urged againft that conclufion.

M. Tillet, being in his own mind perfuaded that tin renders gold fo brittle that it cannot be reduced to thin leaves, and far lefs be made to pafs through the wire-plate but by virtue of repeated annealing, and peculiar treatment, which gold of the ufual ductility does not require, determined, from refpect to M. Alchorne, to repeat his experiments.

His firft experiment* confifted in mixing 24 grains of fine gold with one of tin which contained no arfenic. 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, fo hollowed out as to fupport the mixed metal during fufion. He even fprinkled a fmall quantity of calcined borax upon the metal, in order that the fufion might be more fudden, that the metal might flow together, and the tin unite with the gold, without allowing time for it to become calcined. This alloy was fpeedily fufed by the enameller's lamp, and reduced into a fmall button without any lofs of weight. It was then flattened carefully beneath the hammer; but, notwithftanding his utmoft precaution in this refpect, it cracked, and at laft broke into three pieces, its thicknefs 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 refult was the fame.

* *Memoirs of the Academy of Sciences at Paris for the year* 1790.

He next alloyed 4 ounces of gold, of the finenefs of 22 carats, with 1 gros 24 grains of tin deprived of arfenic, or, in other words, with 4 pennyweights of tin; and thefe two metals being reduced into fmall pieces, were mixed together, put into a crucible, and urged by the ftrong heat of a forge with two pair of bellows. When their fufion appeared to be complete, he poured the metal into a fmall ingot mould proportioned to the quantity.

The ingot thus obtained had loft fcarcely any thing of the weight of the two metals that compofed 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 fix 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 confiderable effort to give it any degree of curvature, or bring it to the flexibility it would have poffeffed if no tin had entered into its compofition. Not fatisfied, however, with the inference naturally flowing from this circumftance, he proceeded to the proper teft by hammering, particularly with the edge of the hammer, in order that the bar might be lengthened, and by that means fubmitted to the moft decifive proof. He did not obferve, during the continuation of this procefs, till the bar was reduced to about two-thirds of its firft thicknefs, that its edges were cracked, or exhibited much of the appearance of brittlenefs; but as he was apprehenfive that this accident might happen by too long hammering, he divided the bar by cutting off the part which had been hammered out. This part was placed in the midft of lighted charcoal, in order that, by a moderate annealing, it might recover the ftate of malleability it poffeffed 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 fuffered thefe to cool, he forged them again. They were extended with confiderable eafe, though with fome cracks at the edges; but they did not yet fatisfy the whole of his enquiries. He therefore annealed one of the two laft mentioned pieces a fecond time, and referved the other in its hard-hammered ftate to be paffed between the laminating rollers. The annealed part, which might have the thicknefs of about a fhilling, broke in the fire, though the heat was very gentle, into four or five portions. The longeft of thefe portions, which beft refifted the action of the fire, bent and twifted itfelf, and fhewed, by this ftate of ftrong contraction in different directions, that it had tended to break and become divided into fmall portions, fimilar to thofe which had already feparated from it.

Satisfied by this experiment that the piece of the mixed ingot which he had kept in its hammer-hardened ftate would not bear annealing, he determined to extend it ftill more between the rollers, fetting them up very gradually, in order that the fracture, if it fhould take place, might be principally owing to the brittlenefs of the material, and not to the force of compreffion to which it was fubjected. By this management he fucceeded in extending the metal to double its length notwithftanding its hardnefs, and rendering it as thin as ftrong paper; though the edges were cracked through their whole length like the teeth of a faw. But this accident is not at all furprifing, when it is confidered that gold, though alloyed fimply with copper, whatever may be the caufe, does not poffefs its ufual 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 fufion, or unequal mixture of the two metals, he melted the whole ingot over again with the utmoft precaution; but in vain. The metal was as brittle as formerly, and would not bear annealing.

He next fufed fix ounces of pure gold of 24 carats with 2 gros, or 6 penny-weights of tin, taking every poffible precaution to have the metals completely mixed. When the whole was in perfect fufion, he poured the mixture into an ingot mould, and obtained an ingot rather longer and cleaner than the two former. As foon 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 thicknefs of one line, or thereabouts, he cut it off for feparate treatment. By moderate annealing it maintained its integrity; and, with the exception of a few cracks, it paffed the laminating rollers without breaking. As he was fearful, neverthelefs, that it might break in fome part if he continued to laminate it, he gave it a flight annealing. It had fcarcely acquired a cherry-rednefs between the charcoal, before it broke into five or fix parts, fome of which were fimply bended or twifted, and others flat as they quitted the rollers. Among the annealed pieces of this extremity

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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 consistence 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 therefore equal upon both, the metals, notwithstanding this treatment, preserve their natural consistence, even tho' the heat be carried near the point of fusion."

Gold, Goldoni.

Gold-Leaf. See *Gold-Leaf* (*Encycl.*), 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; insomuch 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-eightieth 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 skilful, 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 humourous 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 *Cicognini*, 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 probity 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

gradually from the pit to the ftage, entered into a familiar acquaintance with the actors. When the feafon of comic performances was over, and the actors were to remove to Chiozza, young Goldoni made his efcape in their company. This was the firft fault he committed, which, according to his own confeffion, drew a great many others after it. His father had intended him to be a phyfician, like himfelf: the young man, however, was wholly averfe to the ftudy. He propofed afterwards to make him an advocate, and fent him to be a practitioner in Modena. An horrid ceremony of ecclefiaftical jurifdiction, at which he was prefent, infpired him with a melancholy turn, and he determined to become a capuchin.

His father, perceiving the whimfical, inconftant humour of his fon, feigned to fecond this propofal, and promifed to go and prefent him to the guardian of the capuchins in Venice, in the hope that, after fome ftay in that extenfive and merry city, his melancholy fit would ceafe. The fcheme fucceeded; for the young man, indulging in all the fafhionable diffipation of the place, was cured of his foolifh refolution. It was however neceffary for him to be fettled in fome employment; and he was prevailed upon by his mother, after the death of his father, to exercife the profeffion of a lawyer in Venice. By a fudden reverfe 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 refident of Venice in the capacity of fecretary; where becoming acquainted with the manager of the theatre, he wrote a farce, entitled *Il Gondoliere Veneziano*, the Venetian Gondolier; which was the firft comic production of his that was performed and printed. Some time after, Goldoni broke with the Venetian refident, 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 infenfibly united to the company, for which he compofed feveral pieces. Having removed along with them to Genoa, he was for the firft time feized with an ardent paffion for a lady, who foon afterwards became his wife. He returned with the company to Venice, where he difplayed, for the firft time, the powers of his genius, and executed his plan of reforming the Italian ftage. He wrote the *Momolo*, *Courtifan*, the *Squanderer*, and other pieces, which obtained univerfal admiration.

Feeling a ftrong inclination to refide fome time in Tufcany, he repaired to Florence and Pifa, where he wrote *The Footman of Two Mafters*, and *The Son of Harlequin loft and found again*. He returned to Venice, and fet about executing more and more his favourite fcheme of reform. He was now attached to the theatre of St Angelo, and employed himfelf in writing both for the company and for his own purpofes. The conftant toils he underwent in thefe engagements impaired his health. He wrote, in the courfe of twelve months, fixteen new comedies, befides forty-two pieces for the theatre; among thefe many are confidered as the beft of his productions. The firft edition of his works was publifhed in 1753, in 10 vols. 8vo. As he wrote afterwards a great number of new pieces for the theatre of St Luca, a feparate edition of thefe was publifhed, under the title of *The New Comic Theatre*: among thefe was the *Terence*, called by the author his *favourite*, and judged to be the mafter-piece of his works. He made another journey to Parma, on the invitation of Duke Philip, and from thence he paffed to Rome. He had compofed 59 other pieces fo late as the year 1761, five of which were defigned for the particular ufe of Marque Albergati Capacelli, and confequently adapted to the theatre of a private company. Here ends the literary life of Goldoni in Italy.

Through the channel of the French Ambaffador in Venice, he had received a letter from Mr Zenuzzi, the firft actor in the Italian theatre at Paris, containing a propofal for an engagement of two years in that city. He accordingly repaired to Paris, where he found a felect and numerous company of excellent performers in the Italian theatre. They were, however, chargeable with the fame faults which he had corrected in Italy; and the French fupported, and even applauded in the Italians, what they would have reprobated on their own ftage. Goldoni wifhed to extend even to that country his plan of reformation, without confidering the extreme difficulty of the undertaking. Scurrilities and jefts, which are ever accompanied by actions, geftures, and motions, are the fame in all countries, and almoft perfectly underftood even in a foreign tongue: while the beauties of fentiment and dialogue. and other things which lead to the underftanding of characters and intrigues, require a familiar acquaintance with the tongue of the writer.

The firft attempt of Goldoni towards his wifhed-for reform, was the piece called *The Father for Love*; and its bad fuccefs was a fufficient warning to him to defift from his undertaking. He continued, during the remainder of his engagement, to produce pieces agreeable to the general tafte, and publifhed twenty-four comedies; among which *The Love of Zelinda and Lindor* is reputed the beft.

The term of two years being expired, Goldoni was preparing to return to Italy, when a lady, reader to the dauphinefs, mother to the late king, introduced him at court, in the capacity of Italian mafter to the princeffes, aunts to the king. He did not live in the court, but reforted there at each fummons, in a poftchaife fent to him for the purpofe. Thefe journeys were the caufe of a diforder in the eyes, which afflicted him the reft of his life; for being accuftomed to read while in the chaife, he loft his fight on a fudden, and in fpite of the moft potent remedies, he could never afterwards recover it entirely. For about fix months lodgings were provided him in the chateau of Verfailles. The death, however, of the dauphin, changed the face of affairs. Goldoni loft 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 penfion of four thoufand livres a-year. This fettlement would not have been fufficient for him, if he had not gained, by other means, farther fums. He wrote now and then comedies for the theatres of Italy and Portugal; and, during thefe occupations, was defirous to fhew to the French that he merited a high rank among their dramatic writers. For this purpofe, he neglected nothing which could be of ufe to render himfelf mafter of the French language.

He

Goldoni, Good Hope. 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 1796 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."

Good Hope. 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 Almaviva having left in pledge at the suttling-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

to

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 matts, 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 industrious 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 pearl, 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.

As

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 barns 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 *Capse 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 who can understand but little of this fluctuation, is sure to be duped.

Good Hope

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

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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 benefice 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
1799. 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 semicircle, 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 venerial disease. It is thus described in the third volume (English translation) of Perouse's Voyage round the World.

Calyx quadrified, 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° 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 bason G (Plate 240, 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 of

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 (*kalakar*), 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° 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 Kinardie, 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 Kinardie, 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,

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 displeased 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 contrived solely for destruction, and would soon be known by the enemy, he rather deserved to be punished, and urged 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 javelines 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 raised 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 practised, the grinding of tools is attended with great inconveniency, arising from the production or developement 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 procured 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 proposed 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 decomposed, and emitted an empyreumatic smell. The stone was then suffered 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 pressed 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

Grose.

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 loses 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 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 tinctured 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 jocularity."

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 the

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 ſurpriſe.

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.*

Plate XXIX.

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 infinitment 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 Françoiſe*, 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 relicts 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 *Encyclopædia* 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

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.

* *Transactions of the Royal Irish Academy.*

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 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 1308 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 atmospherical 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 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 cascabel 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 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 410624½ 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, fizes, fome as fmall as the grains of the fineft Battel powder, he placed a number of vertical fcreens of very thin paper, one behind another, at the diftance of 12 inches from each other; and loading a common mufket repeatedly with this powder, fometimes without and fometimes with a wad, he fired it againft the foremoft fcreen, and obferved the quantity and effects of the unconfumed grains of powder which impinged againft it. The fcreens were fo 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 diftance from the muzzle of the gun to the firft fcreen was not always the fame; in fome of the experiments it was only 8 feet, in others it was 10, and in fome 12 feet.

The charge of powder was varied in a great number of different ways; but the moft interefting experiments were made with one fingle large grain of powder, propelled by fmaller and larger charges of very fine grained powder.

Thefe large grains never failed to reach the fcreen; and though they fometimes appeared to have been broken into feveral pieces by the force of the explofion, yet they frequently reached the fcreen entire; and fometimes paffed through all the fcreens (five in number) without being broken.

When they were propelled by large charges, and confequently with great velocity, they were feldom on fire when they arrived at the firft fcreen; which was evident, not only from their not fetting fire to the paper (which they fometimes did), but alfo from their being found fticking in a foft board, againft which they ftruck, after having paffed through all the five fcreens; or leaving vifible marks of their having been impinged againft it, and being broken to pieces and difperfed by the blow. Thefe pieces were often found lying on the ground; and from their forms and dimenfions, 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 diminifhed by the combuftion before the fire was put out, on the globe being projected into the cold atmofphere.

That thefe globes or large grains of powder were always fet on fire by the combuftion of the charge, can hardly be doubted. This certainly happened in many of the experiments; for they arrived at the fcreens on fire, and fet fire to the paper; and in the experiments in which they were projected with fmall velocities, they were often feen to pafs through the air on fire; and when this was the cafe, no veftige was to be found. They fometimes paffed on fire through feveral of the foremoft fcreens without fetting them on fire, and fet fire to one or more of the hindmoft, and then went on and impinged againft the board which was placed at the diftance of twelve inches behind the laft fcreen.

The Count then proceeds to mention another experiment, in which the progreffive combuftion of gunpowder was fhewn in a manner ftill more ftriking, and not lefs conclufive.

A fmall piece of red hot iron being dropped down into the chamber of a common horfe piftol, and the piftol being elevated to an angle of about 45 degrees, upon dropping down into its barrel one of the fmall globes of powder (of the fize of a pea), it took fire, and was projected into the atmofphere by the elaftic fluid generated in its own combuftion, leaving a very beautiful train of light behind it, and difappearing all at once like a falling ftar. This amufing experiment was repeated very often, and with globes of different fizes. When very fmall ones were ufed fingly, they were commonly confumed entirely before they came out of the barrel of the piftol; but when feveral of them were ufed together, fome, if not all of them, were commonly projected into the atmofphere on fire.

As the flownefs of the combuftion of gunpowder is undoubtedly the caufe which has prevented its enormous and almoft incredible force from being difcovered, our author deduces, as an evident confequence, that the readieft way to increafe its effects, is to contrive matters fo as to accelerate its inflammation and combuftion. This may be done in various ways; but, in his opinion, the moft fimple and moft effectual manner of doing it would be to fet fire to the charge of powder, by fhooting (through a fmall opening) the flame of a fmaller charge into the midft of it.

He contrived an inftrument on this principle for firing cannon three or four years ago; and it was found, on repeated trials, to be ufeful, convenient in practice, and not liable to accidents. It likewife fuperfedes the neceffity of ufing priming, of vent tubes, port-fires, and matches; and on that account he imagined it might be of ufe in the Britifh navy, but it does not appear to have been received into practice.

Another infallible method of increafing very confiderably the effect of gunpowder in fire-arms of all forts and dimenfions, would be to caufe the bullet to fit the bore exactly, or without windage, in that part of the bore at leaft where the bullet refts on the charge; for when the bullet does not completely clofe the opening of the chamber, not only much of the elaftic fluid, generated in the firft moment of the combuftion of the charge, efcapes by the fide of the bullet; but what is of ftill greater importance, a confiderable part of the unconfumed powder is blown out of the chamber along with it in a ftate of actual combuftion, and, getting before the bullet, continues to burn on as it paffes through the whole length of the bore; by which the motion of the bullet is much impeded.

The lofs of force which arifes from this caufe, is in fome cafes almoft incredible; and it is by no means difficult to contrive matters fo as to render it very apparent, and alfo to prevent it.

If a common horfe-piftol be fired with a loofe ball, and fo fmall a charge of powder that the ball fhall not be able to penetrate a deal board fo deep as to ftick in it when fired againft it from the diftance of fix feet; the fame ball, difcharged from the fame piftol with the fame charge of powder, may be made to pafs quite through one deal board, and bury itfelf in a fecond placed behind it, merely by preventing the lofs of force which arifes from what is called windage, as he found more than once by actual experiment.

The Count has in his poffeffion a mufket, from which, with a common charge of powder, he fires two bullets at once with the fame velocity that a fingle bullet is difcharged from a mufket on the common conftruction with the fame quantity of powder. And, what renders the experiment ftill more ftriking, the diameter

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. I.

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.

"The

Gut-tie.

" 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 ſevere 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 ſenna, 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.

Gut-tie, Guz.

" 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 ſear 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 || Harriot.

HANCES, Hanches, Haunches, or *Hanſes*, 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 Suſſex.

Harriot.

" 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 Analyticæ Praxis, ad æquationes 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

at

Harriot. at Paris, obferved to the famous geometrician Roverval, that thefe improvements in analyfis had been already made thefe fix years in England, and fhewed him afterwards Harriot's *Artis Analyticæ Praxis;* which, as Roverval was looking over, at every page he cried out, *Oui! oui! il l'a vu! Yes! yes! he has feen it!* Des Cartes had alfo been in England before Harriot's death, and had heard of his new improvements and inventions in analyfis.

"Now all this relates to Harriot the celebrated analyft; but it has not hitherto been known that Harriot was an eminent aftronomer, both theoretical and practical, which firft appears by thefe manufcripts; among which, the moft remarkable are 199 obfervations of the fun's fpots, with their drawings, calculations, and determination of the fun's rotation about his axis. There is the greateft probability that Harriot was the firft difcoverer of thefe fpots, even before either Galileo or Scheiner. The earlieft intelligence we have of the firft difcovered folar fpots is of one Joh. Fabricius Phryfius, who in the year 1611 publifhed at Wittemberg a fmall treatife, intitled, *De Maculis in Sole obfervatis & apparente eorum cum Sole converfione narratio.* Galileo, who is commonly accounted the firft difcoverer of the folar fpots, publifhed his book, *Iftoria e Dimonftrazioni intorne alle Machie Solare e loro accidente*, at Rome in the year 1613. His firft obfervation 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 difcovered thefe fpots in the month of April in the year 1611, at Rome, in the Quirinal Garden, but had fhewn them feveral months before (*molti mefi innanzi*) to his friends in Florence; and that the obfervations of the difguifed Apelles (the Jefuit Scheiner, a pretender to this firft difcovery) were not later than the month of October in the fame year; by which the epoch of this difcovery was fixed to the beginning of the year 1611. But a paffage in the firft letter of Galileo's works, pa. 11. gives a more precife term to this difcovery. Galileo there fays in plain terms, that he had obferved the fpots in the fun 18 months before. The date of this letter is May 24. 1612; which brings the true epoch of this difcovery to the month of November 1610. However, Galileo's firft produced obfervations are only from June 2. 1612, and thofe of father Scheiner of the month of October in the fame year. But now it appears from Harriot's manufcripts, that his firft obfervations of thefe fpots 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 Jofeph a Cofta's *Natural and Moral Hiftory of the Weft Indies;* in which he relates, that in Peru there are fpots to be feen in the fun which are not feen in Europe: and hence it is probable, that Harriot took the hint of looking for fuch fpots. Befides, it is not unlikely, that living with fo munificent a patron, Harriot got from Holland the new invented telefcopes much fooner than they could reach Galileo, who at that time lived at Venice. Harriot's very careful and exact obfervations of thefe fpots, fhew alfo that he was in poffeffion of the beft and moft improved telefcopes of that time; for it appears he had fome with magnifying powers of 10, 20, and 30 times. At leaft there are no earlier obfervations of the folar fpots extant than his; they run from December 8. 1610, till January 18. 1613. I compared the correfponding ones with thefe obferved by Galileo, between which I found an exact agreement. Had Harriot had any notion about Galileo's difcoveries, he certainly would have alfo known fomething about the phafes of Venus and Mercury, and efpecially about the fingular fhape of Saturn, firft difcovered by Galileo; but I find not a word in all his papers concerning the particular figure of that planet.

"I found likewife (continues Dr Zach) among the papers of Harriot a large fet of obfervations on the fatellites of Jupiter, with drawings of them, their pofitions, and calculations of their revolutions and periods. His firft obfervation of thofe difcovered fatellites, I find to be of January 16. 1610; and they go till February 26. 1612. Galileo pretends to have difcovered them January 7. 1610; fo that it is not improbable that Harriot was likewife the firft difcoverer of thefe attendants of Jupiter.

"Among his other obfervations of the moon, of eclipfes, of the planet Mars, of folftices, 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 obferved with a crofs-ftaff, by meafuring their diftances from fixed ftars; whence thefe obfervations are the more valuable, as comets had before been but grofsly obferved. Kepler himfelf obferved the comet of 1607 only with the naked eye, pointing out its place by a coarfe eftimation, without the aid of an inftrument; and the elements of their orbits could, in defect of better obfervations, be only calculated by them. The obfervations of the comet of the year 1607 are of the more importance, even now for modern aftronomy, as this is the fame 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 thefe coarfe obfervations; for which reafon he only affigned the term of its return to the fpace 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 fpace. But a greater light may now be thrown upon this matter by the more accurate obfervations on this comet by Mr Harriot. In the month of October 1785, when I converfed upon the fubject of Harriot's papers, and efpecially on this comet, with the celebrated mathematician M. de la Grange, director of the Royal Academy of Sciences at Berlin, he then fuggefted to me an idea, which, if brought into execution, will clear up an important point in aftronomy. It is well known to aftronomers how difficult a matter it is to determine the mafs, or quantity of matter, in the planet Saturn; and how little fatisfactory the notions of it are that have hitherto been formed. The whole theory of the perturbations of comets depending upon this uncertain datum, feveral attempts and trials have been made towards a more exact determination of it by the moft eminent geometricians of this age, and particularly by la Grange himfelf; but never having been fatisfied with the few aud uncertain data heretofore obtained for the refolution of this problem, he thought that Harriot's obfervations on the comet of 1607, and the modern ones of the fame comet in 1759, would fuggeft a way of refolving the problem *à pofteriori;* that of determining by

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 *loca geometrica*, 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 Baeck and Dr Wargentin, 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 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 Baeck, 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, 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.

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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 ozier work, consisting of open strait 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 *stang* 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 hat 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. rifes a little more than two feet and a half above the ground; and the flope towards the kettle is confiderably rapid, fo that the whole battery is little more than fix feet in diameter. The quantity of fulphuric acid added to the liquor is not fufficient to give a four tafte, but only renders it rough to the tongue. In this liquor, heated rather higher than unpractifed hands could bear, the article is dipped from time to time, and then worked on the planks with a roller, and alfo by folding or rolling it up, and opening it again; in all which, a certain degree of care is at firft neceffary, to prevent the fides from felting together; of which, in the more advanced ftages of the operation, there is no danger. The imperfections of the work now prefent themfelves to the eye of the workman, who picks out knots and other hard fubftances with a bodkin, and adds more felt upon all fuch parts as require ftrengthening. This added felt is patted down with a wet brufh, and foon incorporates with the reft. The beaver is laid on towards the conclufion of this kind of working. Mr Nicholfon could not diftinctly learn why the beer grounds were ufed with beaver-hats. Some workmen faid, that by rendering the liquor more tenacious, the hat was enabled to hold a greater quantity of it for a longer time; but others faid, 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 obferves, that the manufacturers who now follow the eftablifhed practice, may not have tried what are the inconveniences this addition is calculated to remove."

Our author's correfpondent, however, affigns feveral reafons for the addition of thofe dregs, which, he fays, ought to be thick, and the foureft that can be got. 1. Vitriol (fulphuric acid) would harden the hat too much, which is kept mellow by the dregs. 2. The dregs are faid by the workmen to hold or fill the body, whilft a little vitriol cleanfes it of the dirt, &c. that may be on the rabbit or other wools. 3. Another advantage attending the ufe 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 ftiffened, the dregs form a body within the hat, fufficiently ftrong or retentive to keep the glue from coming through amongft the nap. 4. Vitriol (fulphuric acid) alone purges or weakens the goods too much; confequently half of the quantity does better with the addition of dregs, as it allows the body to be made clofer by more work.

Of thefe four reafons for the ufe of dregs, the laft alone appears to us perfpicuous or at all fatisfactory. But be this as it may, acid of fome kind gives a roughnefs to the furface of the hair, which facilitates the mechanical action of felting; and Mr Collinfon informed Mr Nicholfon, that in a procefs, called *carotting*, they make ufe of nitrous acid. In this operation, the material is put into a mixture of the nitrous and fulphuric acids in water, and kept in the digefting heat of a ftove all night; by which means the hair acquires a ruddy or yellow colour, and lofes part of its ftrength.

"It muft be remembered, that our hat ftill poffeffes the form of a cone, and that the whole of the feveral actions it has undergone have only converted it into a foft flexible felt, capable of being extended, though with fome difficulty, in every direction. The next thing to be done is to give it the form required by the wearer. For this purpofe, the workman turns up the edge or rim to the dipth of about an inch and a half, and then returns the point back again through the centre or axis of the cap, fo far as not to take out this fold, but to produce another inner fold of the fame depth. The point being returned back again in the fame manner, produces a third fold; and thus the workman proceeds, until the whole has acquired the appearance of a flat circular piece, confifting 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 preffes it down with his hand, at the fame 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 ftring down the fides of the block, he caufes the next part to affume the figure of the crown, which he continues to wet and work, until it has properly difpofed itfelf round the block. The rim now appears like a flounced or puckered appendage round the edge of the crown; but the block being fet upright on the plank, the requifite figure is foon given by working, rubbing, and extending this part. Water only is ufed in this operation of fafhioning or blocking; at the conclufion of which it is preffed out by the blunt edge of a copper implement for that purpofe.

"Previous to the dyeing, the nap of the hat is raifed or loofened out with a wire brufh, or carding inftrument. The fibres are too rotten after the dyeing to bear this operation. The dyeing materials are logwood, and a mixture of the fulphates of iron and of copper, known in the market by the names of green copperas and blue vitriol. As the time of Mr Collinfon was limited, and my attention, fays Mr Nicholfon, was more particularly directed to the mechanical proceffes, I did not go into the dye-houfe; but I have no doubt that the hats are boiled with the logwood, and afterwards immerfed in the faline folution. I particularly afked whether galls were ufed, and was anfwered in the negative.

"The dyed hats are, in the next place, taken to the ftiffening fhop. One workman, affifted by a boy, does this part of the bufinefs. He has two veffels, or boilers, the one containing the grounds of ftrong beer, which cofts feven fhillings per barrel, and the other veffel containing melted glue, a little thinner than it is ufed by carpenters. Our author particularly afked, whether this laft folution contained any other ingredient befides glue, and was affured that it did not. The beer grounds are applied in the infide of the crown to prevent the glue from coming through to the face, and alfo, as he fuppofes, to give the requifite firmnefs at a lefs expence than could be produced by glue alone. If the glue were to pafs through the hat in different places, it might, he imagines, be more difficult to produce an even glofs upon the face in the fubfequent finifhing. The glue ftiffening is applied after the beer grounds are dried, and then only upon the lower face of the flap, and the infide of the crown. For this purpofe the hat is put into another hat, called a ftiffening hat, the crown of which is notched, or flit open in various directions. Thefe are then placed in a hole in a deal board,

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 pores

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 senega, 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 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.

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 articled 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. Hawkins.

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 authorised 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, Westminister; 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 Abbey, 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-earnt 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 no 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° 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

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, 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 canes, 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, confortable 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 present 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.

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 Georgium 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 *Johanna*, 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 Hinzuan 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 Swisserland, but never saw one before, round the bosom of which the clouds were almost continually rolling, whiles it 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 conduced more to the variety of this enchanting prospect, than the many rows of palm trees, especially the tall and graceful *Arecas*, 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 *Matsamúdò* lay on our left, remarkable at a distance for the tower of the principal mosque, which was built by Halímah, 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 *Hinzúàn*."

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.

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The master of the frigate learned from one of the chiefs a few curious circumstances concerning the government of *Hinzuan;* which he found to be a monarchy 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 *Mufti* 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 *Hinzuan*, 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 *Hinzuan*, 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 *Hinzuan*, 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 *Hinzuan*, and departed thence for Europe or India: he shewed me the captain's promissory notes for sums, 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 *instrumenta 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.

Hirundo, Hispaniola.

HIRUNDO Esculenta (see Hirundo, *Encycl.* nº 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 Linnæus. For an account of the eatable nests of these birds, and the manner of collecting them, see Cap and Button 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 *Encyclopædia*. 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 negativing 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 ;

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 caution 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 armed bodies, and waited with anxious expectation to ſee what meaſures the colonial aſſembly would adopt. Hiſpaniola.

During theſe diſſenſions, the negro ſlaves, into whoſe minds had been ſeduloufly 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

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 ſtript 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 reſtored 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 orillon, 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 ſcapement, 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.

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. Horne.

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 curvilineal 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 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. Uunder 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 Buxtorf. 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 ſurpriſed. 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 biaſſed 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 relinquiſhed. 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 impreſſed 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 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 the

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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 conſiſts 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 ſeparately, 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 intimate

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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, Asperfed 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, *Encycl.*), 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 Canterbury, 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.

* See Scotch Episcopalians in this Supplement.

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 preferments

were

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 more fully 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, horologiography, 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 to 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 deſart, 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.

Proceedings of the African Aſſociation.

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 ſea-

Houghton. fon and the tide of ebb afforded of fwimming his horfe and his affes acrofs the ftream; and having by thofe means avoided the parties who were fent for his deftruction, he proceeded with much difficulty on the fouthern fide of the river, to that diftrict of Cantor which is oppolite to the kingdom of Woolli. There he repaffed the Gambia, and fet a meffenger to inform the king of his arrival, and to requeft a guard for his protection.

An efcort, commanded by the king's fon, was immediately difpatched; and the Major, whofe intended prefent had been announced, was kindly received, and hofpitably entertained at Medina.

The town is fituated at the diftance of about 900 miles by water from the entrance of the Gambia; and the country adjacent abounds in corn and cattle, and, generally fpeaking, in all things that are requifite for the fupport, or effential to the comfort of life. Two different fects of religion diftinguifh rather than divide the people; the one is compofed of the profeffors of the Mahomedan faith, who are called Bufhreens; the other, and, it is faid, the more numerous, confifts of thofe who, denying the miffion of the prophet, avow themfelves deifts, and from their cuftom of drinking with freedom the liquors of which he prohibited the ufe, are denominated Sonikees or drinking men.

In a letter from Major Houghton to his wife, which a feaman preferved from the wreck of a veffel in which the difpatches to the fociety were loft, the Major indulged the reflections that naturally arofe from his paft and prefent fituations. A bilious fever had attacked him foon after his arrival in the Gambia; but his health was now unimpaired—a confpiracy had affailed his life; but the danger was paffed—the journey from Junkiconda had expofed him to innumerable hardfhips; but he was now in poffeffion of every gratification which the kindnefs of the king or the hofpitality of the people could enable him to enjoy. Delighted with the healthinefs of the country, the abundance of the game, the fecurity with which he made his excurfions on horfeback, and, above all, with the advantages that would attend the erection of a fort on the falubrious and beautiful hill of Fatetenda, where the Englifh once had a factory, he expreffes his earneft hope that his wife will hereafter accompany him to a place in which an income of ten pounds a-year will fupport them in affluence; and that fhe will participate with him in the pleafure of rapidly acquiring that vaft wealth which he imagines its commerce will afford.

While, in this manner, he indulged the dream of future profperity, and with ftill more ample fatisfaction contemplated the eclat of the difcoveries for which he was preparing, but in the purfuit of which he was retarded by the abfence of the native merchant, for whofe company he had engaged, he found himfelf fuddenly involved in unexpected and irrefiftible misfortune. A fire, the progrefs of which was accelerated by the bamboo roofs of the buildings, confumed with fuch rapidity the houfe in which he lived, and with it the greateft part of Medina, that feveral of the articles of merchandize, to which he trufted for the expences of his journey, were deftroyed; and to add to his affliction, his faithlefs interpreter, who had made an ineffectual attempt on his goods, difappeared with his horfe and three of his affes; a trade gun which he had purchafed on the river foon afterwards burft in his hands, and wounded him in the face and arm: and though the hofpitable kindnefs of the people of the neighbouring town of Barraconda, who cheerfully opened their houfes to more than a thoufand families, whofe tenements the flames had confumed, was anxioufly exerted for his relief; yet the lofs of his goods, and the confequent diminution of his travelling fund, were evils which no kindnefs could remove. Houghton.

It was in this fituation that, wearied with the fruitlefs hope of the return of the native trader, with whom he had contracted for his journey, he refolved to avail himfelf of the company of another flave merchant, who was lately arrived from the fouth, 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 affes, which the fervants of the flave merchant offered to drive with their own, and which carried the wreck of his fortune; and journeying by a north-eaft courfe, arrived on the fifth day at the uninhabited frontier which feparates the kingdoms of Woolli and Bondou.

He had now paffed the former limit of European difcovery; and while he remarked with pleafure the numerous and extenfive population of this unvifited country, he obferved, 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 overfpread a confiderable part of Senegambia; and their religious diftinctions are fimilar to thofe which prevail in the kingdom of Woolli.

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 fouth-weftern boundary of the kingdom of Bambouk. Its ftream was exhaufted by the advanced ftate of the dry feafon, and its bed exhibited an appearance of flate intermixed with gravel.

Bambouk is inhabited by a nation, whofe woolly hair and fable complexions befpeak them of the negro race, but whofe character feems to be varied in proportion as the country rifes from the plains of its weftern divifion to the highlands of the eaft. Diftinguifhed into fects, like the people of Woolli and Bondou, by the different tenets of Mahomedans and Deifts, they are equally at peace with each other, and mutually tolerate the refpective opinions they condemn.

Agriculture and pafturage, as in the negro ftates on the coaft of the Atlantic, are their chief occupations; but the progrefs which they have made in the manufacturing arts, is fuch as enables them to fmelt their iron ore, and to furnifh the feveral inftruments of hufbandry and war. Cloth of cotton, on the other hand, which in this part of Africa feems to be the univerfal wear, they appear to weave by a difficult and laborious procefs; and to thefe two circumftances it is probably owing, that with them the meafure of value is not, as on the coaft, a bar of iron, but a piece of cloth.

The common vegetable food of the inhabitants appears to confift of rice; their animal, of beef or mutton. A liquor, prepared from fomented honey, fupplies the want of wine, and furnifhes the means of thofe feftive entertainments that conftitute 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 Woolli had cheerfully accepted; but to his great disappointment an ungracious reception, a sullen 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 y 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 negociation, 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 Tisheet (a place by the salt pits in the Great Desart, 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 Desart. 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 fhewn at a diftance the fpot in the woods to which his body was dragged, and where it was left a prey to corruption.

Thus perifhed, in the prime of life, Major Houghton, a man whofe travels enlarged the limits of European difcovery, and whofe accounts of the places which he vifited were ftrongly confirmed by the intelligence which the Britifh conful 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 curiofity among men of fcience, fince it was firft mentioned to a committee of the African Affociation about the year 1790. The perfon from whom they received their information was an Arab, of the name of Shabeni; who faid that the population of Houffa, where he had refided two years, was equalled only (fo far as his knowledge extended) by that of London and Cairo: and, in his rude unlettered way, he defcribed the government as monarchical, yet not unlimited; its juftice as fevere, but directed by written laws; and the rights of landed property as guarded by the inftitutions of certain hereditary officers, whofe functions appear to be fimilar to thofe of the Canongoes of Hindoftan (fee CANONGOES in this *Suppl.*); and whofe important and complicated duties imply an unufual degree of civilization and refinement. For the probity of the merchants of Houffa, the Arab expreffed the higheft refpect; but remarked, with indignation, that the women were admitted to fociety, and that the honour of the hufband was often infecure. Of their written alphabet, he knew no more than that it is perfectly different from the Arabic and the Hebrew characters; but he reprefented the art of writing as common in Houffa. And when he defcribed the manner in which their pottery is made, he gave, unknowingly to himfelf, a reprefentation of the ancient Grecian wheel. In paffing to Houffa from Tombuctoo, in which laft city he had refided feven years, he found the banks of the Niger more numeroufly peopled than thofe of the Nile, from Alexandria to Cairo; and his mind was obvioufly impreffed with higher ideas of the wealth and grandeur of the empire of Houffa, than of thofe of any kingdom which he had feen, England alone excepted.

The exiftence of the city of Houffa, and of the empire thus defcribed by Shabeni, was ftrongly confirmed by letters which the committee received from his Majefty's confuls at Tunis and Morocco; and it has been put beyond all poffibility of doubt by Mr Park, who received from various perfons fuch concurring accounts of it, as could not be the offspring of deliberate falfehood. From a well-informed fhereeff, who had vifited Houffa, and lived fome years at Tombuctoo, he learned that the former of thefe cities was the largeft that the fhereeff had ever feen; and by comparing this man's account of its population with that of various other cities, of which Mr Park had feen one or two, we can hardly eftimate the inhabitants of Houffa at a lefs number than 100,000. Many merchants, with whom our traveller converfed, reprefented Houffa as larger, and more populous, than Tombuctoo, and the trade, police, and government, as nearly the fame in both. In that cafe, the king of Houffa and chief officers of ftate muft be Moors, and zealots for the Mahometan religion; but they cannot be fo intolerant as the fovereign of Tombuctoo and his minifters; for in Houffa, Mr Park was told that the Negroes are in greater proportion to the Moors than in Tombuctoo, and that they have likewife fome fhare 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 fkill; and their files, in particular, are much fuperior to thofe of Great Britain and France. The confuls at Tunis and Morocco affured the committee of the African Affociation, that at both thefe courts the eunuchs of the feraglio are brought from Houffa.

Houffa, Houzouanas.

To thofe who may ftill entertain doubts of fo much refinement being to be found in the interior parts of a country, confidered as peculiarly favage, we fhall only obferve, in the words of the committee of affociation, that it is by no means "impoffible that the Carthaginians, who do not appear to have perifhed with their cities, may have retired to the fouthern parts of Africa; and though loft to the Defart, may have carried with them to the new regions which they occupy fome portion of thofe arts and fciences, and of that commercial knowledge, for which the inhabitants of Carthage were once fo eminently famed. In Major Rennel's laft map of North Africa, Houffa is placed in 16° and about 20′ N. Lat. and 4° 30′ E. Long.

HOUZOUANAS, are a wandering people, who inhabit that part of Africa, which, in a direction from eaft to weft, extends from Caffraria to the country of the Greater Nimiquas (See NIMIQUAS in this *Suppl.*) According to the map prefixed to Vaillant's new travels, the diftrict occupied by the Houzouanas lies between 16° and 29° eaft longitude. Of its breadth from fouth to north we are ignorant, but it begins at the 23d parallel, aud ftretches northward probably a great way.

M. Vaillant is inclined to believe, that the Houzouanas are the original ftem of the various nations, inhabiting at prefent the fouthern part of Africa, and that from them all the tribes of the eaftern and weftern Hottentots are defcended. The people themfelves know nothing of their origin; but to the queftions that are put to them on the fubject, they always reply, that they inhabit the country which was inhabited by their anceftors. 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 firft eftablifhed themfelves at the Cape, the Houzouanas inhabited the country of Camdebo, the fnowy mountains, and the diftrict that feparates thefe mountains from Caffraria. Become neighbours to the colony, in confequence of its extending itfelf towards them, they at firft lived on peaceable terms with the planters; and, as they difplayed more intelligence and greater activity than the Hottentots, they were even employed in preference to affift in cultivating the land and in forming the fettlement. This good underftanding and harmony were, however, foon interrupted by that multitude of lawlefs banditti fent from Holland to people the country.

Thofe worthlefs profligates wifhed to enjoy the fruits of the land without the trouble of tilling it. Educated, befides, with all the prejudices of the whites, they imagined that men of a different colour were born only

to

Houzouanas.

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 necessity 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 surprising

Houzouanas.

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.

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 surprise 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 and

Hungary-water.

and enterprising spirit of this singular people be true, might not the African Association send 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.

HUNGARY-WATER, is spirit of wine distilled upon rosemary, and which therefore contains its oily and strong-scented essence (see PHARMACY, n° 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, Montpelier, and other places in Languedoc, in which that plant grows in great abundance.

Hist. of Inventions.

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 *Encyclopædia*, 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.

In

(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:

"℞. 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 Chefelden, at the requeft of Dr Hunter, permitted him to attend at Chelfea Hofpital; and he there learned the firft rudiments of furgery.

The following winter he was fo far advanced in the knowledge of human anatomy, as to inftruct the pupils in diffection, to whom Dr Hunter had very little time to pay attention. This office, therefore, fell almoft entirely upon him, and was his conftant employment during the winter feafon.

In the fummer months of 1750, Mr Hunter attended the hofpital at Chelfea; in 1751, he became a pupil at St Bartholomew's, and in the winter was prefent at operations occafionally, whenever any thing extraordinary occurred. The following fummer he went to Scotland; and in 1753 entered, it is difficult to conceive for what reafon, as a gentleman commoner at St Mary-hall, Oxford. In 1754 he became a furgeon's pupil at St George's hofpital, where he continued during the fummer months; and in 1756 was appointed houfe-furgeon.

In the winter 1755, Dr Hunter admitted him to a partnerfhip in his lectures, and a certain portion of the courfe was allotted to him; befides 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 fkilfully made, became an object of admiration; many were wanting for the ufe of the lectures; and the Doctor being himfelf an enthufiaft for the art, left no means untried to infufe into his brother a love for his favourite purfuits. How well he fucceeded, the collection afterwards made by Mr Hunter will fufficiently evince.

Anatomy feems to have been a purfuit for which Mr Hunter's mind was peculiarly fitted, and he applied to it with an ardour and perfeverance of which there is hardly an example. His labours were fo ufeful to his brother's collection, and fo gratifying to his difpofition, that although in many other refpects they did not agree, this fimple tie kept them together for many years.

Mr Hunter worked for ten years on human anatomy; during which period he made himfelf mafter of what was already known, as well as made fome addition to that knowledge. He traced the ramifications of the olfactory nerves upon the membranes of the nofe, and difcovered the courfe of fome 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 alfo the firft who difcovered the exiftence of the lymphatic veffels in birds.

Many parts of the human body being fo complex, that their ftructure could not be underftood, nor their ufes afcertained, Mr Hunter was led to examine fimilar parts in other animals, in which the ftructure was more fimple, and more within the reach of inveftigation; this carried him into a wide field, and laid the foundation of his collection in comparative anatomy.

In this new line of purfuit, this active inquirer began with the more common animals, and preferved fuch parts as appeared by their analogy, or in fome other way, to elucidate the human economy. It was not his intention to make diffections of particular animals, but to inftitute an inquiry into the various organizations by which the functions of life are performed, that he might thereby acquire fome knowledge of general principles.

So eagerly did Mr Hunter attach himfelf to comparative anatomy, that he fought by every means in his power the opportunities of profecuting it with advantage. He applied to the keeper of wild beafts in the Tower for the bodies of thofe which died there; and he made fimilar applications to the men who fhowed wild beafts. He purchafed all rare animals which came in his way; and thefe, with fuch others as were prefented to him by his friends, he entrufted to the fhowmen to keep till they died, the better to encourage them to affift him in his labours.

His health was fo much impaired by exceffive attention to his purfuits, that in the year 1760 he was advifed to go abroad, having complaints in his breaft which threatened to be confumptive. In October of that year, Mr Adair, infpector-general of hofpitals, appointed him a furgeon on the ftaff; and in the following fpring he went with the army to Bellifle, leaving Mr Hewfon to affift his brother during his abfence.

Mr Hunter ferved, while the war continued, as fenior furgeon on the ftaff, both in Bellifle and Portugal, till the year 1763; and in that period acquired his knowledge of gun-fhot wounds. On his return to England he fettled in London; where, not finding the emoluments from his half-pay and private practice fufficient to fupport him, he taught practical anatomy and operative furgery for feveral winters. He returned alfo, with unabated ardour, to comparative anatomy; and as his experiments could not be carried on in a large town, he purchafed for that purpofe, about two miles from London, a piece of ground near Brompton, at a place called Earl's Court, on which he built a houfe. In the courfe of his inquiries, this excellent anatomift afcertained the changes which animal and vegetable fubftances undergo in the ftomach when acted on by the gaftric juice; he difcovered, by means of feeding young animals with madder (which tinges growing bones red), the mode in which a bone retains its fhape during its growth; and explained the procefs of exfoliation, by which a dead piece of bone is feparated from the living.

His fondnefs for animals made him keep feveral of different kinds in his houfe, which, by attention, he rendered familiar with him, and amufed himfelf by obferving their peculiar habits and inftincts; but this familiarity was attended with confiderable rifk, and fometimes led him into fituations of danger, of which the following is a remarkable inftance:

Two leopards, which were kept chained in an outhoufe, had broken from their confinement, and got into the yard among fome dogs, which they immediately attacked; the howling this produced alarmed the whole neighbourhood; Mr Hunter ran into the yard to fee what was the matter, and found one of them getting up the wall to make his efcape, the other furrounded by the dogs; he immediately laid hold of them both, and carried them back to their den; but as foon as they were fecured, and he had time to reflect upon the rifk of his own fituation, he was fo much agitated, that he was in danger of fainting.

On the fifth of February 1767, he was chofen a fellow 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 surgeon's 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 trochar. 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 Gillaroo trout, commonly called in Ireland 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.

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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 Croonion 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.

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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 solicious for some improvement in medical

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medical education; and, with the affiftance of Dr Fordyce, inftituted a medical fociety, which he allowed to meet in his lecture rooms, and of which he was chofen one of the patrons. This fociety, called the *Lyceum Medicum Londinenfe*, under his aufpices and thofe of Dr Fordyce, has acquired confiderable reputation, both from the numbers and merits of its members.

In the year 1786, in confequence of the death of Mr Middleton, Mr Hunter was appointed deputy furgeon-general to the army. He now publifhed his work upon the Venereal Difeafe, which had been long expected by the public; and, if we may judge from the rapid fale of the firft edition, thefe expectations have not been difappointed. He alfo publifhed a work entitled, Obfervations on certain Parts of the Animal Economy. In this work he has collected feveral of his papers inferted in the Philofophical Tranfactions, which related to that fubject, having permiffion from the prefident and council of the Royal Society to reprint them; there are alfo Obfervations upon fome other parts of the Animal Economy, which had not before been publifhed. This work met with a very ready fale.

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 fame fpecies; and a third upon the Anatomy of the Whale Tribe. Thefe papers procured him the honour of receiving Sir John Copley's annual gold medal, given as a mark of diftinguifhed abilities.

His collection, which had been the great object of his life, both as a purfuit and an amufement, was now brought into a ftate of arrangement; and gave him at length the fatisfaction of fhewing to the public a feries of anatomical facts formed into a fyftem, by which the economy of animal life was illuftrated. He fhewed 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 fpring. This cuftom he continued to his death.

Upon the death of Mr Adair, which happened in the year 1792, Mr Hunter was appointed infpector-general of hofpitals, and furgeon-general to the army. He was alfo elected a member of the Royal College of Surgeons in Ireland. In the year 1791, he was fo much engaged in the duties of his office, as furgeon-general to the army, and his private practice, that he had little time to beftow upon his fcientifical objects; but his leifure time, fmall as it was, he wholly devoted to them.

In 1792, he was elected an honorary member of the Chirurgo-Phyfical Society of Edinburgh, and was chofen one of the vice-prefidents of the Veterinary College, then firft eftablifhed in London. He publifhed in the Tranfactions of the Society for the Improvement of medical and chirurgical Knowledge, of which fociety he was one of the original members and a zealous promoter, three papers on the following fubjects: Upon the Treatment of Inflamed Veins, on Introfufception, and on a Mode of conveying Food into the Stomach in Cafes of Paralyfis of the Œfophagus.

He finifhed his Obfervations on the Economy of Bees, and prefented them to the Royal Society. Thefe obfervations were made at Earl's Court, and had engaged his attention for many years; every inquiry into the economy of thefe infects had been attended by almoft unfurmountable difficulties; but thefe proved to him only an incitement, and the contrivances he made ufe of to bring the different operations of thefe indefatigable animals to view were almoft without end.

Earl's Court to Mr Hunter was a retirement from the fatigues of his profeffion; but in no refpect a retreat from his labours; there, on the contrary, they were carried on with lefs interruption, and with an unwearied perfeverance. From the year 1772 till his death, he made it his cuftom to fleep there during the autumn months, coming to town only during the hours of bufinefs in the forenoon, and returning to dinner.

It was there he carried on his experiments on digeftion, on exfoliation, on the tranfplanting of teeth into the combs of cocks, and all his other inveftigations on the animal economy, as well in health as in difeafe. The common bee was not alone the fubject of his obfervation, but the wafp, hornet, and the lefs known kinds of bees, were alfo objects of his attention. It was there he made the feries of preparations of the external and internal changes of the filk worm; alfo a feries of the incubation of the egg, with a very valuable fet of drawings of the whole feries. The growth of vegetables was alfo a favourite fubject 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 confidered as the great object of his life, muft be allowed to be a proof of talents, affiduity, and labour, which cannot be contemplated without furprife and admiration. It remains an unequivocal teft of his perfeverance and abilities, and an honour to the country in whofe fchools he was educated, and by the patronage of which he was enabled on fo extenfive a fcale to carry on his purfuits. In this collection we find an attempt to expofe to view the gradations of Nature, from the moft fimple ftate in which life is found to exift, up to the moft perfect and moft complex of the animal creation—man himfelf.

By the powers of his art, this collector has been enabled fo to expofe, and preferve in fpirits or in a dried ftate, the different parts of animal bodies intended for fimilar ufes, that the various links of the chain of perfection are readily followed and may be clearly underftood.

This collection of anatomical facts is arranged according to the fubjects they are intended to illuftrate, which are placed in the following order: *Firft*, Parts conftructed for motion. *Secondly*, Parts effential to animals refpecting their own internal economy. *Thirdly*, Parts fuperadded for purpofes connected with external objects. *Fourthly*, Parts for the propagation of the fpecies and maintenance or fupport of the young.

Mr Hunter was a very healthy man for the firft forty years of his life; and, if we except an inflammation of his lungs in the year 1759, occafioned moft probably by his attention to anatomical purfuits, he had no complaint of any confequence during that period. In the fpring of 1769, in his forty firft year, he had a regular fit of the gout, which returned the three following fprings, but not the fourth; and in the fpring of 1773, having met with fomething which very forcibly affected his mind, he was attacked at ten o'clock in the forenoon with a pain in the ftomach, attended with all the fymptoms of *angina pectoris*. In the life of him prefixed to his *Treatife on the Blood, Inflammation, and Gun-fhot Wounds*,

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 *pese-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 furement of denfities exceeding that of pure water, is commonly diftinguifhed by the name of the *Hydrometer for falts*.

The hydrometer for fpirits is conftructed upon the fame principle; but in this the counterpoife is fo adjufted, that moft part of the ftem rifes above the fluid when immerfed in pure water, and the graduations to exprefs inferior denfities are continued upwards. A folution of ten parts by weight of falt in ninety parts of pure water, affords the firft point, or zero, upon the ftem; and the mark indicated by pure water is called the tenth degree; whence, by equal divifions, the remaining degrees are continued upwards upon the ftem as far as the fiftieth degree.

Thefe experiments, in both cafes, are made at the tenth degree of Reaumur, which anfwers very nearly to fifty-five of Fahrenheit.

HYDRUS, or WATER SERPENT, one of the new fouthern conftellations, including only ten ftars.

HYGROMETER, is an inftrument of fo much importance to the meteorologift, that it becomes us to give fome account of every improvement of it which has fallen under our notice. In the *Encyclopædia*, the principles upon which hygrometers are conftructed have been clearly ftated, and the defects of each kind of hygrometer pointed out.

Inftead of hairs or cat-gut, of which hygrometers of the firft kind are commonly made, Caffebois, a Benedictine monk at Mentz, propofed to make fuch hygrometers of the gut of a filk-worm. When that infect is ready to fpin, there are found in it two veffels proceeding from the head to the ftomach, to which they adhere, and then bend towards the back, where they form a great many folds. The part of thefe veffels next the ftomach is of a cylindric form, and about a line in diameter. Thefe veffels contain a gummy fort of matter from which the worm fpins its filk; and, though they are exceedingly tender, means have been devifed to extract them from the infect, and to prepare them for the above purpofe. When the worm is about to fpin, it is thrown into vinegar, and fuffered to remain there twenty-four hours; during which time the vinegar is abforbed into the body of the infect, and coagulates its juices. The worm being then opened, both the veffels, which have now acquired ftrength, are extracted; and, on account of their pliability, are capable of confiderable extenfion. That they may not, however, become too weak, they are ftretched only to the length of about fifteen or twenty inches. It is obvious that they muft be kept fufficiently extended till they are completely dry. Before they attain to that ftate, they muft be freed, by means of the nail of the finger, from a flimy fubftance which adheres to them. Such a thread will fuftain a weight of fix pounds without breaking, and may be ufed for an hygrometer in the fame manner as cat-gut; but we confefs that we do not clearly perceive its fuperiority.

To an improvement of the hygrometer conftructed on the third principle, ftated in the *Encyclopædia*, M. Hochheimer was led in the following manner:

Mr Lowitz found at Dmitriewfk in Aftracan, on the banks of the Wolga, a thin bluifh kind of flate which attracted moifture remarkably foon, but again fuffered it as foon to efcape. A plate of this flate weighed, when brought to a red heat, 175 grains, and, when faturated with water, 247: it had therefore imbibed, between complete drynefs and the point of complete moifture, 72 grains of water. Lowitz fufpended a round thin plate of this flate at the end of a very delicate balance, faftened within a wooden frame, and fufpended at the other arm a chain of filver wire, the end of which was made faft to a fliding nut that moved up and down in a fmall groove on the edge of one fide of the frame. He determined, by trial, the pofition of the nut when the balance was in equilibrio and when it had ten degrees of over-weight, and divided the fpace between thefe two points into ten equal parts, adding fuch a number more of thefe parts as might be neceffary. When the ftone was fufpended from the one arm of the balance, and at the other a weight equal to 175 grains, or the weight of the ftone when perfectly dry, the nut in the groove fhewed the excefs of weight in grains when it and the chain were fo adjufted that the balance ftood in equilibrio. A particular apparatus on the fame principles as a vernier, applied to the nut, fhewed the excefs of weight to ten parts of a grain. Lowitz remarked that this hygrometer in continued wet weather gave a moifture of more than 55 grains, and in a continued heat of 113 degrees of Fahrenheit only $1\frac{1}{2}$ degree of moifture.

The hygrometer thus invented by Lowitz was, however, attended with this fault, that it never threw off the moifture in the fame degree as the atmofphere became drier. It was alfo fometimes very deceitful, and announced moifture when it ought to have indicated that drynefs had again begun to take place in the atmofphere. To avoid thefe inconveniences, M. Hochheimer propofes the following method:

1. Take a fquare bar of fteel about two lines in thicknefs, and from ten to twelve inches in length, and form it into a kind of balance, one arm of which ends in a fcrew. On this fcrew let there be fcrewed a leaden bullet of a proper weight, inftead of the common weights that are fufpended. 2. Take a glafs plate about ten inches long, and feven inches in breadth, deftroy its polifh on both fides, free it from all moifture by rubbing it over with warm afhes, fufpend it at the other end of the balance, and bring the balance into equilibrium by fcrewing up or down the leaden bullet. 3. Mark now the place to which the leaden bullet is brought by the fcrew, as accurately as poffible, for the point of the greateft drynefs. 4. Then take away the glafs plate from the balance, dip it completely in water, give it a fhake that the drops may run off from it, and wipe them carefully from the edge. 5. Apply the glafs-plate thus moiftened again to the balance, and bring the latter into equilibrium by fcrewing the leaden bullet. Mark then the place at which the bullet ftands as the higheft degree of moifture. 6. This apparatus is to be fufpended in a fmall box of well dried wood, fufficiently large to fuffer the glafs-plate to move up and down. An opening muft be made in the lid, exactly of fuch a fize 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 pleafure from the higheft point of drynefs to the higheft degree of moifture. The box muft be pierced with fmall holes on all the four fides, to give a free paffage to the air; and to prevent moifture from penetrating into

Hygrometer. 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. HYPOTRACHELION, in Architecture, is used for a little frize 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.

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 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.

He contrived 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 *Encyclopedie* 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,

(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, affumed new names, and employed an enigmatical language. Thus, Frederic is called *Luc*; D'Alembert, *Protagoras*, and fometimes *Bertrand*; Voltaire, *Raton*; and Diderot, *Platon*, or its anagram *Tonpla*; while the general term for the confpirators is *Cacouce*. In their fecret meetings they profeffed to celebrate the myfteries of *Mythra*; and their great object, as they profeffed to one another, was to confound the *wretch*, meaning J— C—. Voltaire propofed to eftablifh a colony of philofophifts at Cleves, who, protected by the king of Pruffia, might publifh their opinions without dread or danger; and Frederic was difpofed to take them under his protection, till he difcovered that their opinions were anarchical, as well as impious, when he threw them off, and even wrote againft them.

They contrived, however, to engage the minifters of the court of France in their favour, by pretending to have nothing in view but the enlargement of fcience, in works which fpoke indeed refpectfully of revelation, while every difcovery which they brought forward was meant to undermine its very foundation. When the throne was to be attacked, and even when barefaced atheifm was to be promulgated, a number of impious and licentious pamphlets were difperfed, for fome time none knew how, from a fecret fociety formed at the Hotel d'Holbach at Paris. Thefe were fold for trifles, or diftributed *gratis* to fchoolmafters, and others who were likely to circulate their contents. D'Alembert, Diderot, and Condorcet, who was now affociated with the other confpirators, flattered the ambition of every man among the great, and efpecially of the Duke d'Orleans, the richeft fubject in Europe, and a prince of the blood of France. The firft and the laft of thefe three adepts had, by their mathematical knowledge, got fuch an afcendancy 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 confpirators; and they had contrived, by matchlefs addrefs and unwearied perfeverance, to fill almoft all the feminaries of education with men of their own principles.

Thus was the public mind in France completely corrupted, when the mafon lodges, over which the infamous Orleans prefided, were vifited by a delegation from the German illuminati; and nothing more was neceffary to produce the fect of *Jacobins*, by whofe intrigues and influence, France, as M. Barruel expreffes himfelf, has become a prey to every crime. It was by the machinations of this fect that its foil was ftained with the blood of its pontiffs and priefts, its rich men and nobles; with the blood of every clafs of its citizens, without regard to rank, age, or fex. Thefe difciples of Voltaire were the men who, after having made the unfortunate Louis, his queen, and fifter, drink, to the very dregs, the cup of outrage and ignominy during a long confinement, folemnly murdered them on a fcaffold, proudly menacing all the fovereigns of the earth with a fimilar fate. Yet think not, indignant reader, that the ways of Providence are unequal. The nations of Europe were ripe for chaftifement; and that chaftifement thefe villains were employed to inflict: but their own punifhment did not linger. Voltaire died in agonies of defponding remorfe, which can be exceeded only by the torments of the damned. There is reafon to believe that the end of D'Alembert and Diderot very much refembled 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 conftitution (and thefe alterations have been many) being followed by the execution of thofe by whom the government was previoufly adminiftered.

Jaghire || Jago.

JAGHIRE, affignment made in Bengal by an Imperial grant upon the revenue of any diftrict, to defray civil or military charges, penfions, gratuities, &c.

JAGHIREDER, the holder of a Jaghire.

St JAGO, the largeft and moft populous of the Cape de Verde Iflands, of which fome account has been given in the *Encyclopædia*, is reprefented by Sir George Staunton as liable to long and exceffive droughts, for which no philofophical caufe can be affigned. When the embaffy to China touched at it in the latter end of 1792, it was in a ftate of abfolute famine. Little or no rain had fallen for about three years before. The rivers were almoft all entirely dry. The furface of the earth was, in general, naked of any herbage. The greateft part of the cattle had perifhed, not lefs through drought than want of food. Of the inhabitants many had migrated, and many were famifhed to death. Nor was this calamity peculiar to St Jago. All the iflands of Cape de Verde were faid to have experienced the fame long drought, and to be confequently in a ftate of fimilar defolation. Yet the frequent fhowers which were obferved by the firft navigators who touched at St Jago, induced them to give to the ifland the name of *Pluvialis*; and no change had been obferved in the fteady current of wind, blowing from the eaft, which is common to tropical climates.

"What were the uncommon circumftances (fays Sir George) that took place in the atmofphere of that part of Africa to which the Cape de Verde iflands lie contiguous, or in the vaft expanfe of continent extending to the eaft behind it, and from which this direful effect muft have proceeded, as they happened where no man of fcience exifted to obferve or to record them, will therefore remain unknown; nor is theory bold enough to fupply the place of obfervation. Whatever was the caufe which thus arrefted the bountiful hand of Nature, by drawing away the fources of fertility, it was obfervable, that fome few trees and plants perfevered to flourifh with a luxuriance, indicating that they ftill could extract from the arid earth whatever portion of humidity it was neceffary to derive from thence for the purpofe of vegetable life, though it was denied to others."

Befide the trees of the palm kind, which are often found verdant amidft burning fands, nothing, for example, could be more rich in flavour, or abound more with milky, though corrofive juice, than the afclepias gigantea (fee Asclepias, *Encycl.*), growing plentifully, about feveral feet high, without culture, indeed, but undifturbed, it being of no avail to cut it down in favour of plants that would be ufeful, but required the aid of more moifture from the atmofphere. The jatropha

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fcure, if not fpurious, and abftract mathematics not furnifhing ready accefs to the great, his ideas, when compared with Voltaire's, were grovelling, and (as M. Barruel fays) he was afraid to be feen.

Jago.

pha curcas, or phyfic nut tree, which the French Weft Indians, with fome propriety, call *bois immortel*, and plant, on that account, in the boundaries of their eftates, appeared as if its perpetuity was not to be affected by any drought. Some indigo plants were ftill cultivated with fuccefs in fhaded vales, together with a few cotton fhrubs. Throughout the country fome of thofe fpecies of the mimofa, or fenfitive plant, which grow into the fize of trees, were moft common, and did not appear to languifh. In particular fpots the annona, or fugar apple tree, was in perfect verdure. The boraffus, or great fan palm, lifted, in a few places, its lofty head and fpreading leaves with undiminifhed beauty. In a bottom, about a mile and a half behind the town of Praya, was ftill growing, in a healthy ftate, what may be called for fize a phenomenon in vegetation, a tree known to botanifts by the name of adanfonia, and in Englifh called *monkey bread tree*. The natives of St Jago call it *kabifera*; others, baobab. Its trunk meafured at the bafe no lefs than 56 feet in girth; but it foon divided into two great branches, one rifing perpendicularly, and meafuring 42 feet in circumference; that of the other was about 26. By it ftood another of the fame fpecies, whofe fingle trunk, of 38 feet girth, attracted little notice from the vicinity of its huge companion.

But the annual produce of agriculture was fcarcely to be found. The plains and fields, formerly productive of corn, fugar-canes, or plaintains, nourifhed by regular falls of rain, now bore little femblance of vegetation. Yet in the fmall number of plants which furvived the drought, were fome which, from the fpecimens fent to Europe, were found to have been hitherto unknown. Vegetation quickly, indeed, revived wherever, through the foil, any moifture could be conveyed.

Sir George reprefents Praya, the refidence of the Portuguefe Viceroy, as a hamlet rather than a town. It confifts of about 100 very fmall dwellings, one ftory high, fcattered on each fide 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 fea. Not being commanded by any neighbouring eminence, it was a fituation capable of defence; the fort, however, or battery, was almoft in ruins; and the few guns mounted on it were moftly honey-combed, and placed on carriages which fcarcely held together.

A party belonging to the embaffy croffed the country to the ruins of St Jago, the former capital of the ifland, fituated in the bottom of a vale, through which ran a ftream, then both fmall and fluggifh. On each fide of that ftream are the remains of dwellings of confiderable folidity and fize; and the fragments of glafs luftres, ftill hanging from the ceilings of fome of the principal apartments, denote the elegance or riches that were once difplayed in this now deferted place. Not above half a dozen families remain in it at prefent; the reft abandoned it, or perifhed. Here was ftill, however, an attempt at a flight manufactory of ftripped cotton flips, the fame as are made in the other parts of the ifland, for the ufe of the Africans on the main, who pay for them in flaves, elephants teeth, and that gum which is generally called arabic.

Amidft the ruins of St Jago, the party found a Portuguefe, to whom one of them was recommended, and who received them with the moft cordial hofpitality in his houfe, and treated them with every fpecies of tropical fruits from his garden, lying on each fide the river.

He had been a navigator; and informed them that the ifle of Brava, one of the Cape de Verde's, was a fitter and fafer place for fhips to call at for water and provifions than the ifland of St Jago; that it had three harbours: one called Puerto Furno on the eaft fide of the ifland, from which veffels muft warp, or be towed out by boats; the Puerto Fajendago to the weft; and the Puerto Ferreo to the fouth, which was the beft for large fhips, and into which runs a fmall river. In another of the Cape de Verde iflands, called San Vicente, he obferved that there was alfo a large harbour on the north end, but that frefh water was at fome diftance from it: and there was likewife a good port at Bonavifta. This information of the harbours in the ifle of Brava was confirmed by accounts given by others to Sir Erafmus Gower, who recommends to make a trial of them.

Jaloffs.

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 ftates on the Gambia (See MANDINGOES in this *Supplement*). Their nofes, fays Mr Park, are not fo much depreffed, nor their lips fo protuberant, as thofe of the generality of Africans; and though their fkin is of the deepeft black, they are confidered by the white traders as the moft fightly negroes in that part of the continent where they live. They are divided into feveral independent ftates or kingdoms, which are frequently at war with their neighbours or with each other. In their manners, fuperftitions, and government, they have a greater refemblance to the Mandingoes than to any other nation; but excel them in the manufacture of cotton cloth, fpinning the wool to a finer thread, weaving it in a broader loom, and dyeing it of a better colour. They make very good foap, by boiling ground nuts in water, and then adding a ley of wood afhes. They likewife manufacture excellent iron, which they carry to Bondou to barter for falt. Their language is faid to be copious and fignificant, 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 difplays a generofity of character very uncommon among favages, will afford pleafure to the minds of many of our readers. Almami Abdulkader, fovereign of a Mahomedan kingdom called Foota Torra, fent to Damel, a king of the Jaloffs, an imperious meffage, commanding him and his fubjects to embrace inftantly the faith of the prophet. The ambaffador having got admiffion to the prefence of Damel, ordered fome Bufhreens (*i.e.* Mahomedan negroes) who accompanied him, to prefent the emblems of his miffion. Two knives were accordingly laid before the Jaloff prince, and the ambaffador explained himfelf as follows:

"With this knife (faid he) Abdulkader will condefcend to fhave 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 refufes to embrace it: Take your choice."—Damel coolly told the ambaffador that he had no choice to make;

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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.

* *The historians of the country.*

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, Ice-house.

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, *Encyclopædia*. 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.

* *Proverbs*, xxv. 15.

"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 fome grafs or green fods, covered with dung from the fheep pens, is thrown over it ; and under thefe it is fo well-preferved, that the whole fummer through it is fent the diftance of 60 Spanifh miles to Lifbon.

"When the ancients, therefore, wifhed to have cooling liquors, they either drank the melted fnow, or put fome of it in their wine, or they placed jars filled with wine in the fnow, and fuffered it to cool there as long as they thought proper. That ice was alfo preferved for the like purpofe, is probable from the teftimony of various authors ; but it appears not to have been ufed fo much in warm countries as in the northern. Even at prefent fnow is employed in Italy, Spain, and Portugal ; but in Perfia ice. I have never any where found an account of Grecian or Roman ice-houfes. By the writers on agriculture they are not mentioned."

ICHNOGRAPHY, in architecture, is a tranfverfe or horizontal fection of a building, exhibiting the plot of the whole edifice, and of the feveral rooms and apartments in any ftory ; together with the thicknefs of the walls and partitions ; the dimenfions of the doors, windows, and chimneys ; the projectures of the columns and piers, with every thing vifible in fuch a fection.

JEBB (John), was born in Southampton-ftreet, Covent Garden, London, on the 16th of February 1736. He was the eldeft fon of the Rev. John Jebb, dean of Cafhel, in the kingdom of Ireland. He received the elements of his education in different fchools, and was admitted, July 7, 1753, penfioner in the univerfity of Dublin, whence he removed, November the 9th 1754, to St Peter's college in Cambridge, where he was likewife a penfioner. In January 1757 he proceeded to the degree of B. A. and his place in the diftribution of academical honours was, on that occafion, fecond wrangler, the late eminent mathematician Dr Waring being the firft. In 1758 he obtained the fecond prize of fifteen guineas, annually given by the univerfity to the authors of the beft compofitions in Latin profe, being fenior or middle bachelors of arts. Dr Roberts, afterwards provoft of Eton college, obtained the firft.

In the month of June 1760, Mr Jebb was admitted probationer fellow of St Peter's college, and proceeded to the degree of Mafter of Arts at the commencement in the fame year ; and on the firft of July 1761, was confirmed fellow by Dr Mawfon, bifhop of Ely.

On the 6th of June 1762, he was ordained deacon at Bugden by Dr John Green, bifhop of Lincoln ; and on the 25th of September, 1763, he was admitted by the fame bifhop into prieft's orders.

On the 22d of Auguft, 1764, Mr Jebb was collated by Dr Matthias Mawfon, bifhop of Ely, to the fmall vicarage of Gamlingay, near Potton, in Bedfordfhire, upon the recommendation of Dr Law, mafter of Peterhoufe. On the 17th of the following October, he was elected by the univerfity 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 Cambridgefhire. Upon cafting up the votes, there appeared to be for Mr Jebb 91, for Mr Turner 73 ; and accordingly he was inftituted into the fame the 15th of December following.

On the 29th of the fame month, (December 1764) Mr Jebb married Anne, eldeft daughter of the Rev. James Torkington, rector of Little Stukeley, in Huntingdonfhire, and of lady Dorothy Sherard, daughter of Philip, fecond earl of Harborough.

Early in the year 1765, Mr Jebb, together with the Rev. Robert Thorpe, fellow of Peterhoufe, and the Rev. George Woollton, fellow of Sidney college, publifhed, in a fmall quarto, a comment on thofe parts of Sir Ifaac Newton's *Principia* which more immediately relate to the fyftem of the world. The title of the joint work of thefe able and judicious philofophers was, "Excerpta quædam e Newtoni principiis philofophiæ naturalis, cum notis variorum." A work, of which the univerfity of Cambridge continues to bear teftimony to the excellence, by the general ufe of it in the courfe of academical education.

Mr Chappelow profeffor of Arabic, dying on the 14th of January 1768, Mr Jebb offered himfelf a candidate for the vacant chair ; but it was given to Dr Hallifax, afterwards bifhop of Gloucefter ; a man of deferved celebrity, of whom we regret that it was not in our power to give a biographical fketch.

On July 10, 1769, Mr Jebb was inftituted to the vicarage of Flixton, near Bungay, in Suffolk, on the prefentation of William Adair, Efq. of Flixton-hall ; and on the 4th of April 1770, was inftituted to the united rectories of Homersfield and St Crofs, parifhes contiguous to Flixton, upon the fame prefentation : being alfo, in the fummer of the fame year, nominated chaplain to Robert earl of Harborough. In confequence of the acceffion of thefe preferments, though not confiderable in themfelves, he refigned, fome time in the month of October 1771, the rectory of Ovington, which he had received from the univerfity ; and Mr Sheepfhanks, fellow of St John's college, was elected in his place.

Dr Hallifax fucceeding to the profefforfhip of civil law, in the month of October 1770, upon the death of Dr Ridlington, Mr Jebb once more folicited that of Arabic, which Dr Hallifax then vacated : but he had by this time difplayed fuch an innovating fpirit in religion, that the univerfity gave the vacant profefforfhip to Mr Craven, a man refpected even by Mr Jebb and his friends.

Early in the year 1771, a defign was formed of applying to parliament for relief in the matter of fubfcription to the liturgy, and thirty-nine articles of the Church of England ; and in the profecution of this defign Mr Jebb took a very active part. He attended different meetings of the difcontented clergy, held at the Feathers tavern, London, affifted in the drawing up of their petition, and wrote their circular letter, which gave to the public an account of their aims. He bufied himfelf at the fame time in making various attempts to bring about what he called a reformation of the univerfity of Cambridge : but finding them fruitlefs, he retired, on the 25th of June 1772, to Bungay, where he ftudied French and Italian, and proceeded in a plan of fome *political* or *conftitutional lectures*.

He had by this time ceafed to read the prayers of the church, though he ftill continued to preach occafionally ; and the Archdeacon of Suffolk, holding, this year, his ufual vifitation of fome neighbouring parifhes in the church of Flixton, Mr Jebb preached fuch a fermon againft fubfcription, as drew upon himfelf a public rebuke from the Archdeacon, in the prefence of the clergy. "Much altercation, (fays he) enfued ; 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 throghout 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 knowledg 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 Essex-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

leaving behind him, among men of different persuasions, very different characters. By the dissenters he is seldom mentioned but as the *Great Jebb*; 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 Mus, *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 characterised: 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."

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.

1 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-instate 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 misticism. 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 shew 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.

2 Art of the founder.

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.

3 The sect divided into classes or

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!

Illuminati.

4 Preparation and

" 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 free-masonry, 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 Areopagites*.

" 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 intimacies, 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).

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 sociable" 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 negociations; 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."

9 To be seduced by whatever means;

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.

Flectere 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."

There

(B) As a specimen of the journals kept by the insinuators, and of the characters which the illuminees selected for

There was alſo another deſcription of men of whom Weiſhaupt very wiſely judged that they would be admirably fitted for the diffuſſion 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 inſinuators. When the choice of this inſinuator is approved, the ſuperiors determine which of the inſinuators 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.

12 And young men,

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 inſinuators) 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."

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

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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 ſallow; 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 extaordinary 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 imself; "for the vengeance of secret societies is not a common vengeance; it is the hidden fire of wrath. It is irreconcileable; 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 order. 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 *Adarpahascht;* 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 interesting 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 centinel, and noting down regularly observations upon the defects and merits of his pupil, which he always sent to his superiors.

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. 16 Novice obliged to draw his own character.

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:

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?* 17 Power of life and death claimed by the society.

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*.

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, 18 Admission to the degree of Minerval.

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 serve 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 degree of minor illuminee. The Minerval was rigorously scrutinized, whether he was ready to submit to every torture, or even to commit 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 Minor illuminees 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

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and demonſtrate how neceſſary ſecret ſocieties are for the attainment of a better order of things."

23
Scotch novice.

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.

24
Candidates for higher degrees ſubmit to new trials.

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 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.

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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, combate 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

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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 insinuators, 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 vail 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 antient 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 perfect, and a philosophy more elevated? And, in the mean time, is it not advisable to disseminate the truth in secret societies? Illuminati.

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.

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.

27 Instructions previous to admission.

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 proſylete 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 proſelyte 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.

28 The illuminees enemies to commerce.

29 Their morality;

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."

30 And blaſphemies of Chriſt.

The impious hierophant then proceeds, with matchleſs blaſphemy, to repreſent the Redeemer of mankind as teaching, like the Grecian ſophiſts, an exoteric 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 reinſtate mankind in their ORIGINAL EQUALITY and LIBERTY, and to prepare the means. This explains in what

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 proſelyte who has heard it without ſhuddering, may flatter himſelf with being

31 Preparatory rites to

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 proſelyte, 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 writings 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 *hindering 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.*"

34 Qualifications for the degree of regent.

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. "1*ſt*, 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.

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 fix-

35 Admiſſion to this degree.

ed 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:

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 be no longer suffered; and when *the clod of useful sciences shall be cast side* (C)!

36 Sign of the degree.

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 serious 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 illuminized 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."

37 Objects of the degrees of magus and man-king.

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 *shocking 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

(C) This will naturally surprise our readers; but it could not surprise 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).

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 illuminized; and is it improbable that this blaſphemer, who was arrayed in the inſignia of the epopts, 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.

38 Atheiſm and

"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 deſart. 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, 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!

* See Doig's *Letters on the Savage State.*

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 illuminiſm 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.

40 The laſt ſecret of the order.

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-

41 Propoſal 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 step-daughters 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 confess 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 Spartacus.

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 illuminized ladies express a wish that the French might invade and conquer England; for then, said they, *tea and coffee would be cheaper!*

* Dr Robison's *Proofs of a Conspiracy*.

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 Barruel; 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 Subordination 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 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*.

44 Their mode of correspondence;

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. Barruel, indicated on the outside of the letter. The *provincial* opens the letters of the *minor* and *major* illuminees which are directed *Soli*; the *Quibus licets* 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.

45 And of giving importance to their order,

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 ascendency 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 taste

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
46 it be generally underſtood that *he is one of us.*

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 INFERIOR LODGES OF FREEMASONRY ARE 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 perſonate 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 Leipſic 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 illuminiſed maſters wiſh them to believe.

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 47
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 illuminizing 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.

Illuminiſm of France

The ſtate of free maſonry was at that time peculiarly 48
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 *Roſicrucians,* and the *knights Kadeſh.* 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 baſtile, 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 Weiſhaupt, which very quickly diffuſed the light of illuminiſm through the whole kingdom. Inſtead of *Spartacus* Weiſhaupt, *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!

By means of free maſonry.

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

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(A) This information was communicated to us by a gentleman of character, who was at Leipſic 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 fundamental principles of illuminism;

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 wish 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.

Illuminati ‖ Imperfect.

50 Exemplified in the conduct of the illuminees.

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; *Herbæ quæ habent qualitatem 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 villany, 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 $\sqrt[4]{-a^4}$, &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 $xx + aa = 0$, 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

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 Impulſion.

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.

1 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 expiſcation 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 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 it 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.

2 Laws of impulſion diſcovered by Wallis, Wrenn, and Huyghens

At laſt the three eminent mathematicians, Dr Wallis, Sir Chriſtopher Wrenn, and Huyghens, about the ſame time, and unknown to each other, diſcovered the ſimple and beautiful laws of colliſion, and communicated them to the Royal Society of London in 1668 (Phil. Tranſ. n° 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 proportional 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 augumented, 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.

3 Impulse said to be the only cause of motion.

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 WHATEVER 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 flote-grass 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° 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

4 The application of this principle is hazardous.

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 authorised 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'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!"

6 We learn the existence of matter chiefly by means of touch.

To accomplish this purpose, we directed the reader's attention to what passes in his own mind when he thinks on 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.

7 The excitement of touch is accompanied by the feeling of exerted pressure.

The philosopher adopts this mode of perception as unquestionable, and allows that, and that alone, to be matter, which invariably produces this sensation by contiguity. 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 painting 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 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, authoriſed 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. Farther, 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.

10
They are generally figurative.

All theſe things are diſtinctly and invariably felt; but they require attention, in order to be ſubjects of recollection and after-conſideration. From this, and no other ſources, are derived all our notions of corporeal preſſure, of counter preſſure, of action, re-action, 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.

11
We obſerve many preſſures.

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 ſome

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, preſſurre, 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 preſſion. 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 reſile 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 copious 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 bodies, and produce all the effects of real animal preſſure. 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.

13 Many preſſures are inexplicable by impulſion.

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?

14 All preſſures do not produce a ſenſible motion.

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 $\frac{1}{10}$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° 95.). Now the effect of the motion of the ſecond ſpring is to keep the preſſure of the firſt

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 press 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 transfusing 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 motion, 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 Impulsiveness 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 motion

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 re-action. 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 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 addictus 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 ατομοι, 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*.

20
Therefore to be learned only by observing nature.

Therefore let us quit entirely the barren and trackless fields of abstraction, and rest satisfied with contemplating *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

God

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 ecstacy 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, Freind, 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 so 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 to the production of motion by the collision 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.

Plate XXIX. 22 Examination of the mutual action of magnets.

Let us, therefore, suppose two magnets, A and B (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. 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° 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; 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 reſiling 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 electriſied 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 touching, and if, after having electrified them ſo that Impulſion. 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.

23 First caſe. A moving toward B at reſt.

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 $\frac{1}{100}$th part in $\frac{1}{10}$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,

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 10th 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 $Bx = A \times \overline{a - x}$, $= Aa - Ax$; and $Aa = Ax + Bx$, $= \overline{A + B} \times x$,

25 Namely, $x = \frac{A \times a}{A + B}$

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.*

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 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.

26 But this does not continue, and the magnets ſeparate.

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.

27 The common velocity is attained at the inſtant of neareſt approach.

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.

28 Repulſion is a cauſe adequate to the obſerved effect.

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.

29 Effect when the magnets are unequal.

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

Impulſion.

greateſt proximity and common velocity. Hence we learn that the final velocity of B is $2x$, or $\frac{2Aa}{A+B}$; and the final velocity of A is $\frac{\overline{A-B}\times a}{A+B}$. 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 $a-\frac{2Ba}{A+B}, =\frac{Aa+Ba-2Ba}{A+B}, =\frac{\overline{A-B}\times a}{A+B}$.

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 premiſed, let the magnets be ſet 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 diminution 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 $A\times x$ and $B\times x$, or $\overline{A+B}\times x = A\times a + B\times b$, and $x=\frac{Aa+Bb}{A+B}$. Therefore *the common velocity is had by dividing the ſum of the primitive quantities of motion by the ſum of the quantities of matter.*

31 Common velocity $=\frac{Aa+Bb}{A+B}$ but the magnets ſeparate, and the change is doubled in each.

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 $\frac{Aa+Ab}{A+B}$. Therefore the change made on the velocity of A, at the inſtant of greateſt proximity, is $a-\frac{Aa+Bb}{A+B}$, or $=-\frac{B\times\overline{a-b}}{A+B}$, and the final velocity of A is $a-\frac{2B\times\overline{a-b}}{A+B}$. In like manner, the change produced on the velocity of B is $=\frac{Aa+Bb}{A+B}-b$, or $=+\frac{A\times\overline{a-b}}{A+B}$, and the final velocity of B is $b+\frac{2A\times\overline{a-}}{A+B}$. 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 $a-\frac{2B\times\overline{a-b}}{A+B}$ is $= a-1\times\overline{a-b}, = a-a+b, = b$: and $b+\frac{2A\times\overline{a-b}}{A+B}$ is $= b+1\times\overline{a-b}, = b+a-b, = a$. 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.

31 Magnets moving in oppoſite directions.

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 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 $A a - B b$. 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 $= \frac{A a - B b}{A + B}$ 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 $= A a - B b$. 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 $A a - B b$. Therefore the common velocity x muſt be $= \frac{A a - B b}{A + B}$.

The velocity loſt by A muſt therefore be $a - \frac{A a - B b}{A + B}, = \frac{B \times \overline{a + b}}{A + B}$, and the final velocity will be $a - \frac{2 B \times \overline{a + b}}{A + B}$. The final motion of A will be in the ſame direction as at firſt, if a be greater than $\frac{2 B \overline{a + b}}{A + B}$, otherwiſe it will be in the oppoſite direction.

In like manner, the change of velocity in B is $b + \frac{A a - B b}{A + B}$, becauſe the former velocity b is deſtroyed, and the new velocity is $\frac{A a - B b}{A + B}$ in the oppoſite direction. This is $= \frac{A \times \overline{a + b}}{A + B}$, and the final velocity of B is $= b - \frac{2 A \times \overline{a + b}}{A + B}$.

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 $= \frac{A a + B b}{A + B}$, or $= \frac{A a - B b}{A + B}$, 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.

There are ſome farther general obſervations that may be made on thoſe motions which are of importance.

34 Theſe changes are proportional to the relative motion,

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 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.

35 And reciprocally as the quantities of matter.

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 $\frac{B \times \overline{a \pm b}}{A + B}$ and $\frac{A \times \overline{a \pm b}}{A + B}$. 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.

36 Conservatio momentorum.

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.

37 Conservatio virium vivarum.

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. Therefore,

fore, during the procefs, each body has paffed over an equal fpace, and in every fimilar point it has been acted on by an equal force (although this force be different in different points of this fpace). Therefore, in every inftant, the fimultaneous products of the quantity of matter by the momentary variation of the fquare of the velocity are equal on both fides; and therefore the products of the quantity of matter by the whole change of the fquare of the velocity are alfo equal on both fides. See DYNAMICS, *Suppl.* n° 95. and 110. where $v\dot{v} = \frac{f\dot{s}}{m}$; and therefore $m v \dot{v} = f\dot{s}$, and $m \times \overline{V^2 - v^2}$, or $n \times \overline{v^2 - V^2} = \int f\dot{s}$. Now, fince thefe changes are in oppofite directions, as much is added to one product as is taken from the other, and the fum of the products of the quantities of matter by the fquares of the final velocities, is equal to the fum of the products of the fame quantities of matter by the fquares of the initial velocities.

These two theorems are not principles, but general facts.

This is a particular cafe of the famous CONSERVATIO VIRIUM VIVARUM, claimed as a mighty difcovery by the partizans of Leibnitz, and afcribed to him; but he has no claim whatever to the difcovery. It was communicated to the Royal Society of London in 1668 by Huyghens, as one of the general laws of impulfion, obtaining in what he calls *hard bodies.* Several of the Leibnitzian fchool, indeed, extended it farther than Huyghens had done; fome of them indeed very lately. The obfervation of this general law was foon applied to many excellent purpofes in the folution of very intricate problems; becaufe it often faved the trouble of tracing the intermediate fteps of a complicated procefs. Affured that thefe products were invariable, the mathematician found it an eafy matter to ftate what conditions of the queftion infured this equality of products; and thus the problem was folved. In this manner Daniel Bernoulli gives moft elegant folutions of fome, otherwife almoft intractable, problems in Hydraulics. For fuch reafons, as a mighty aid in mechanical inveftigation, the difcovery of Huyghens is extremely valuable. Its merit in this refpect is perfectly fimilar (though perhaps fomewhat greater) to Des Cartes's obfervation of the *confervatio momentorum.* It is alfo like the obfervation or difcovery of Maupertuis, which he calls *the law of fmalleft action* (indeed it is the fame under a different afpect), or La Grange's *law of virtual velocities*, or D'Alembert's *law of equilibrium of action*;—all of thefe are general facts, laws by which the changes of motion are *obferved* to proceed. But their authors have vaunted them as principles, as caufes, from which to conclude effects; whereas they are really inductions from particular inftances. We muft alfo obferve, that this law of *confervatio virium vivarum* was not deduced either by Huyghens or any of the Leibnitzian fchool, by reafoning from more general principles. It was an expifcation of famenefs in events, diverfified by other circumftances. We do not recollect any author who has given what can be called a demonftration of it, deducing it from principles or laws ftill more general. We apprehend that the prefent cafe of its truth has been fo demonftrated by us. The *principle* is, that "a moving force is to be meafured by the change of motion produced by it:" And the law to which this principle is applied is, that "the mutual repulfions of magnets are equal and oppofite;" and the application is made by means of the "39th propofition of the firft book of Newton's *Principia.*" Our principle, which is the fame with Sir Ifaac Newton's fecond law of motion, is really an axiom of human thought. The propofition is the confequence logically drawn from this axiom; and the law of magnetifm is an obferved fact. We hope to fhew, by and bye, that this propofition, which is our n° 95. of DYNAMICS, is found to obtain in *every* inftance that has been or can be given of the *confervatio virium vivarum*, and that this *confervatio* is only another way of expreffing the propofition. Having done this, we fhall not think ourfelves chargeable with vanity when we fay, that we have given the firft demonftration of this famous law. We cannot refufe ourfelves fome fatisfaction at having done this; becaufe it has been fo highly efteemed, chiefly for the fupport derived from it for the Leibnitzian meafurement of the force of moving bodies by the *fquare of the velocity* which it communicates; whereas it is the logical confequence of the force being proportional to the *fimple velocity.* We have only taken a weapon out of the hands of a plunderer, and reftored it to its lawful owner, Sir Ifaac Newton. *Non ita certandi cupidus, quam propter amorem:* For we muft fay,

Tu pater et rerum inventor, tu patria nobis
Suppeditas precepta, tuifque ex, inclute, chartis
Floriferis ut apes in faltibus omnia libant,
Omnia nos itidem depafcimur aurea dicta
Aurea, perpetuâ femper digniffima vitâ.

We truft that our reader will not think that this minute difcuffion of the mutual actions of magnets or other repelling bodies, in which we have engaged him, has been thrown away, fince it has enabled us to apprehend clearly a cafe of two fuch general laws as the *confervatio momentorum*, and the *confervatio virium vivarum.*

5. In the moment of greateft vicinity and common velocity, there is a certain determinate lofs of the *vires vivæ*, or products of the matter by the fquare of the velocity; and this lofs is proportional to the fquare of the relative motion. The *vires vivæ*, at the commencement of the mutual action, are $= Aa^2 + Bb^2$ (I.) In the moment of greateft proximity, the quantity of matter A + B is moving with the common velocity $\frac{Aa + Bb}{A + B}$; therefore the *vires vivæ* are $= \overline{A+B} \times \frac{\overline{Aa + Bb}^2}{\overline{A+B}} = \frac{\overline{Aa + Bb}^2}{A + B}, = \frac{A^2a^2 + B^2b^2 + AB \times 2ab}{A + B}$ (II.)

38 Vis vivæ loft in the collifion of unelaftic bodies.

$$\text{I.} \times \overline{A+B} = A^2a^2 + B^2b^2 + AB \times \overline{a^2 + b^2}.$$
$$\text{II.} \times \overline{A+B} = A^2a^2 + B^2b^2 + AB \times 2ab.$$
$$\text{Difference} \quad - \quad - \quad - \quad AB \times \overline{a - b}^2.$$

Lofs of *vis viva* $= \frac{AB}{A + B} \times \overline{a - b}^2$, a quantity that is proportional to $\overline{a - b}^2$, the fquare of the relative velocity $a - b$.

Had the bodies been moving in oppofite directions, then (II.) $\times \overline{A + B}$ would have been $A^2a^2 + B^2b^2 - AB \times 2ab$, and the difference from $\overline{Aa^2 + Bb^2} \times \overline{A + B}$ would have been $= AB \times \overline{a + b}^2$, proportional to the fquare of the relative velocity $a + b$.

Such

Impulſion.

Phyſical cauſe of this loſs.

Such is the fact; and we ſhall find it of importance in the great debate about the force of moving bodies. 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 vivæ*. 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.*

40
The motions, in relation to the centre, are reciprocally as the bodies.

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 $= \frac{A \times \overline{a-b}}{A+B}$, and the change of A's motion was $= \frac{B \times \overline{a-b}}{A+B}$.

41
The bodies ſeparate with the ſame relative velocity which they approached.

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.

42
An interpoſed ſpring has the ſame effect with the mutual repulſions.

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 ftriking B; for, as foon as A touches the fpring, it begins to prefs it againft B, and, therefore, to comprefs the fpring. It cannot carry the fpring before it, without the fpring's pufhing B before it. Preffure on B is required for this purpofe. This is fupplied by that natural power which we call elafticity, which is inherent in the fpring; whether it be in motion or at reft. It is not in *action*, but in *capacity*, *faculty*, *capability*, *power*, or by whatever name we may choofe to exprefs the poffeffion. The occafion required for its exertion is compreffion. This is furnifhed by the motion of A; for A cannot advance without compreffing it. This inherent force of the fpring is *known* to act with perfect equality at both ends, in oppofite directions. It exerts equal and oppofite preffures on A and on B; it diminifhes 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 ftill moving fafter than B; and therefore the compreffion and the confequent reaction of the fpring increafes, and ftill more retards A and accelerates B. After fome time, both bodies, with the fpring compreffed between them, are moving with equal velocities; the fpring, however, is ftrongly reacting on both, and muft now caufe them to feparate; ftill retarding A, and accelerating B—They muft feparate more and more, till the fpring regain its quiefcent form, and its elaftic reaction ceafe entirely. During its reftitution, its preffures are the fame as during its compreffion, therefore, the whole change produced on each of the bodies muft be double of what it was when the fpring was in its ftate of greateft compreffion, and the bodies were moving with a common velocity. In fhort, the whole procefs in this example muft be precifely fimilar to that of the magnets in every circumftance relating to the changes of motion in A and B. The common velocity muft be $= \frac{A\,a \pm B\,b}{A+B}$. The final velocity of A muft be $= a - \frac{2\,B\,\overline{a \pm b}}{A+B}$, and that of B muft be $= b + \frac{2\,A\,\overline{a \pm b}}{A+B}$. The motion of the common centre muft be unaffected by the action of the fpring, and the motion of each body, relative to the centre, muft be reciprocally as its quantity of matter, &c. &c.

43
The changes of motion are produced by the inherent forces which connect the particles.

We apprehend that this procefs can fcarcely be called impulfion; A has not ftruck B. The changes of motion can fcarcely be afcribed to forces inherent in A or B, in confequence of their being in motion. Any perfon, not already warped by a theory, will (we think) afcribe them to a force inherent in the fpring; inherent in it, whether at reft or in motion, and only requiring a *continued* compreffion as the proper opportunity for its continued exertion. This fpring may be fuppofed to make a part of B, or of A, or of both; and then, indeed, the force may be faid 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 *elafticity*, inherent in part of the body, but requiring a continued *compreffion* for the production of a continued *repreffion*. The effect of this reaction is modified by the very occafion of the compreffion. This may be the elafticity of another fpring. In this cafe it will only comprefs that fpring.—It may be the advance of a body in motion; the reaction produces a retardation of that motion; it may be the obftacle of a quiefcent body—it will give it motion; or, it may be the abftruction by a body moving more flowly away than the fpring is preffed forward—it will accelerate that motion. Thus, in all thefe cafes, we cannot help diftinguifhing the immediate caufe of thefe changes of motion from the fuppofed force of a moving body. Nay, the procefs of motion is fimilar, even when we fuppofe that the fpring is not a thing external to the body, although attached to it; but that the whole body, or both bodies, are fpringy, elaftic, and therefore compreffible. As foon as the bodies come into fenfible contact, compreffion *muft* begin; for we may fuppofe the bodies to be two balls, which will therefore touch only in one point. The mutual preffure, which is neceffary in order to produce the retardation of A, and the acceleration of B, is exerted only on the foremoft particle of A, and the hindmoft particle B; but no atom of matter can be put in motion, or have its motion any way changed, unlefs it be acted on by an adequate force. The force urging any individual particle, muft be precifely 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 collifion, 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 thofe adjoining. Therefore, when A overtakes B, the foremoft particle of A is immediately retarded—the particles behind it would move forward, if their mutual connection were diffolved in that inftant; but, this remaining, they only approach nearer to the foremoft ftriking particles, and thus make a compreffion, which gives occafion for the inherent elafticity to exert itfelf, and, by its reaction, retard the following particles. Thus each ftratum (fo to conceive it), continuing in motion, makes a compreffion, which occafions the elafticity to react, and, by reacting, to retard the ftratum immediately behind it. This happens in fucceffion: the compreffion and elaftic reaction begin in the anterior ftratum, and take place in fucceffion backward, and the whole body gets into a ftate of compreffion. Things happen in the fame manner in B, but in the contrary direction, the foremoft ftrata being the laft which are compreffed. All this is done in an inftant (as we commonly, but inaccurately fpeak), that is, in a very fmall and infenfible moment of time; but in this moment there is the fame gradual compreffion, increafe of mutual action, greateft compreffion, common velocity, fubfequent reftitution, and final feparation, as in the cafe of bodies with a flender fpring interpofed, or even in the cafe of the mutually repelling magnets. In all the cafes, the changes of motion are produced by the elafticity or the repulfion, and not by the transfufion of the force of motion. The changing force is indeed inherent in the bodies, but not becaufe they are in motion; the ufe of the motion is to give occafion, by continued compreffion, for the continued operation of the inherent elafticity. The whole procefs may be very diftinctly viewed, by making ufe of bodies of fmall firmnefs, fuch as foot-balls, or blown bladders. If blown bladders are ufed, each loaded with fand, or fomething that will require more force, and

44
Internal procefs of change through the fubftance of each body.

confequently

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 quieſcent form of a body is very little diſturbed, it will recover it again. Thus, a common ſoft iron wire of N° 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 $1\frac{1}{2}$ 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, $\frac{1}{10}$th 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 different 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.

46 Effect of this colliſion.

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 obtain, $= \frac{A\,a \pm B\,b}{A + B}$. 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 $= \frac{A\,a}{A + \text{pend}^{m}}$.

What ſhould we now expect to happen in the colliſion of bodies? Such bodies as exhibit perfect elaſticity, when examined by bending, or other ſit 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 *à 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 aërial 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 proportions, *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 Mariotte, but really invented by Wren, and exhibited to the Royal Society of London the week after he communicated his theory of impulsion).

48 Extensive proof of the universality of equal action and reaction.

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 distanti*, 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

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 *e 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. Impulsion.

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 aereal 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 of

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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 ſtrictly 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 aereal 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?

53 Many caſes of doubtful contact.

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° 63—68.

54 Very remarkable caſe of convex lenſes falſely ſeeming to touch.

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 $\frac{1}{89000}$ 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 $\frac{50}{89000}$ of an inch, or $\frac{1}{1780}$ of an inch. Therefore, when

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 $\frac{1}{155}$ 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, $\frac{1}{112}$ 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 ſtrong a preſſure. We then cut out of it, with a lapidary's hollow drill, a piece of $\frac{1}{4}$ 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 $\frac{1}{6}$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!

56
And may impel without touching

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.

And certainly do ſo, even in violent ſtrokes.

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 Newtonian

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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 rectilineal 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 glass, 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 lense 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.

Remark.

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

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 8900th 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 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 appearances 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 $\frac{1}{18}$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.*

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 *saltus*. 62 Physical contact explained.

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, We thus avoid many absurdities.

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 $A \times \overline{a-x} = B \times \overline{x-b}$, 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.

63
Strongest argument for inertia is the composition of force with a previous motion.

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 the 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° 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° 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

Answered.

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 displeased 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 common velocity is $= \frac{A\,a \pm B\,b}{A + B}$; 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.

64 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. Trans.* 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 $m\,s\,v$, is the proper measure of the action. On the authority of this maxim of divine conduct, Maupertuis investigates 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 $A \times \overline{a - x}|^2 + B \times \overline{x - b}|^2$ 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 $-2\,A\,a\,\dot{x} + 2\,A\,x\,\dot{x} + 2\,B\,x\,\dot{x} - 2\,B\,b\,\dot{x} = 0$, 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 curvilineal 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.

65 Enquiry into the distribution of impulse from the point that is struck.

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.

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

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cessary 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 perpendicular 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 C c, so that the line a A, 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 a A, although C moved in the direction C c. Had A been alone, it would have gone off in the direction a A produced. But the force acting in the direction a A is equivalent to the two forces $a d$ and d A, of which d A presses the ball on B at b, and produces the motion. In like manner, another ball E, so laid that b Be is obtuse, will fly off in the direction ED, which may even be opposite to C c. 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.

Demonstration.

We have evident proof, that at a distance which is not unmeasureable 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 $m n$ (fig. 3.) be the distance at which a particle repels another, and let P be a particle situated at a less distance than $m n$ from the surface AC of a solid body. With a radius PA, equal to $m n$, 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 repulsion 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 $m n$; 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.

67
A stroke, whose action passes through the centre of a position of solid body, impels it without rotation.

Our readers are acquainted with the elementary mechanical property of the centre of gravity. If a body 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 mth part of P. Therefore $f = \frac{P}{m}$, and $P = m f$. An accelerating force is estimated by the velocity v, which

Impulsion. which it generates by acting uniformly during some time t, or $v = f\,t$, 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 striken 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.

68 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° 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.

69 Often accompanied by rotation. 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.

70 General theorem. 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 bFH 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° 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.

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

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° 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. Therefore let v be $= V \times \frac{AF}{AH}$; and then $A \times v$ may

71 Efficient velocity. 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 $A \times \overline{v-x}$: 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 $\frac{A \times \overline{v-x}}{B}$. 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 $\frac{A \times \overline{v-x}}{B}$, 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 $\frac{A \times \overline{v-x}}{B}$.

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 $= \frac{A \times \overline{v-x}}{B} : x$, and $x = \frac{A \times \overline{v-x} \times CP}{B \times CG}$, or x $= v \times \frac{A \times CP}{B \times CG} - x \times \frac{A \times CP}{B \times CG}$; wherefore $x \times B \times CG + x \times A \times CP = v \times A \times CP$, and $x \times \overline{B \times CG + A \times CP} = v \times A \times CP$, and $x = v \times \frac{A \times CP}{B \times CG + A \times CP}$, = the velocity remaining in A, eſtimated in the direction FP.

72 Unelaſtic bodies may ſeparate. And u, the velocity with which G will advance, is $x \frac{CG}{CP}$; 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 acted on by a force $= A \times \overline{v-x}$ in the direction FA. This muſt be compounded with A×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° 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 we obtain $x = v \frac{A \cdot \int p r^2 + A \cdot B \cdot GP^2}{\overline{A+B} \cdot \int p r^2 + A \cdot B \cdot GP^2}$

73 Change of progreſſive motion greateſt when the direction of the effective ſtroke paſſes thro' the centres. 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 therefore increaſe the value of $x = v \frac{A \cdot CP}{B \cdot CG + A \cdot CP}$; and conſequently diminiſh the value of $A \times \overline{v-x}$, 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.

74 Importance of this theory to ſeamanſhip, &c. 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.

75 Impulſion on bodies confined to particular paths. 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

Fig. 1.

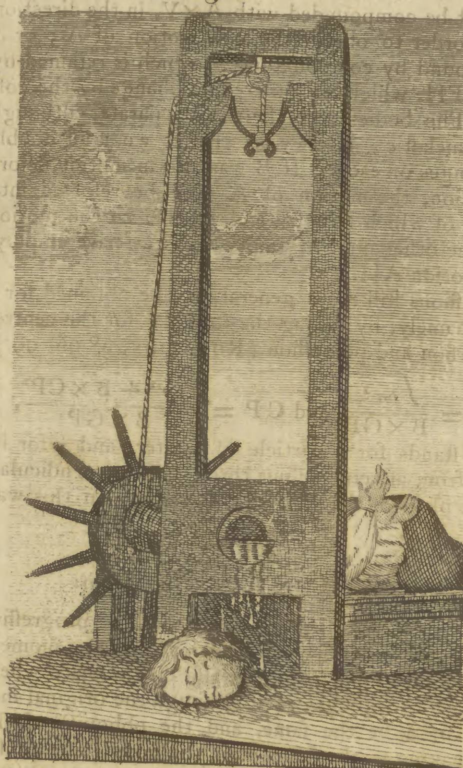
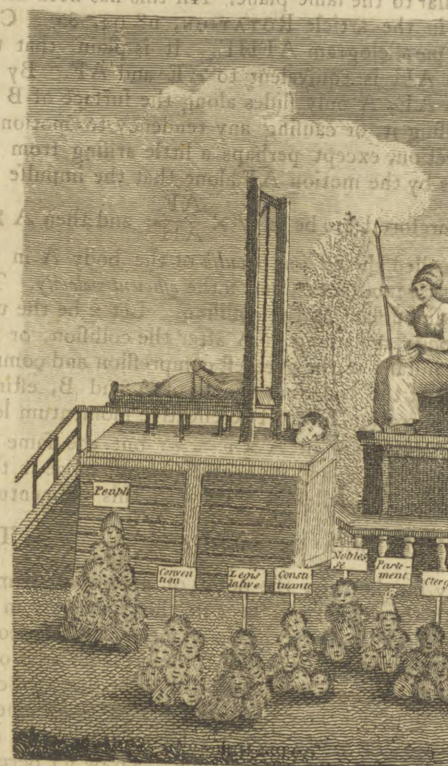
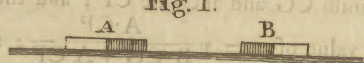


Fig. 2.



IMPULSION

Fig. 1.



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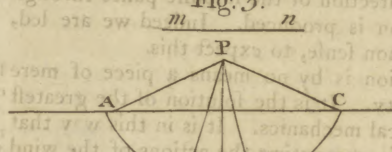

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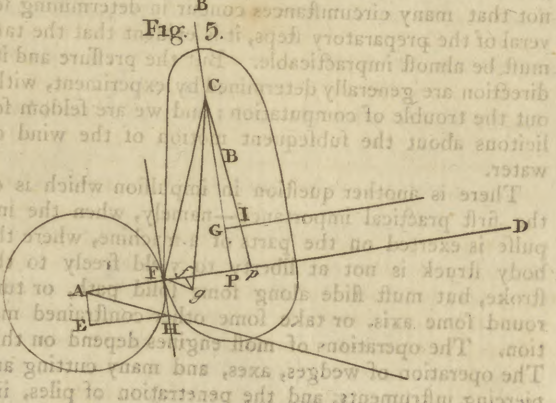
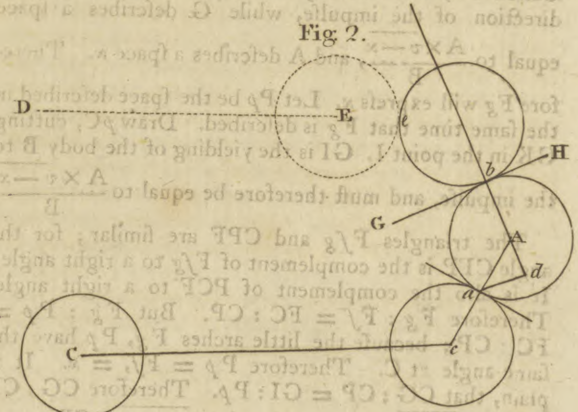


Fig. 2.



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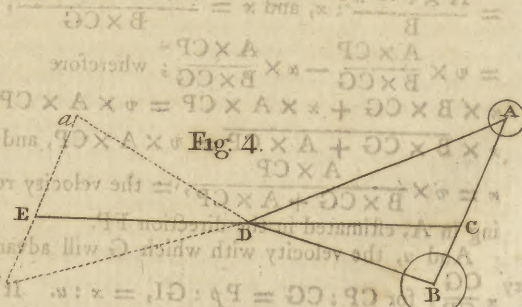

pelled by a rammer, are all ascertained by the same doctrines. But the particular applications can scarcely be elucidated by any classification that occurs to us, the circumstances of the case making such great difference in the result, both in kind and degree. For example, in the simplest case that 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 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.

77 **Great loss of power by the yielding and bending of the materials.**

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 subsultory 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 given

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, Mersennus, 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 Desaguiliers, 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.

78 Conclusion. 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. Moguntiæ 1671.—Leibn. Op. T. II. p. II. 3.

Ejusdem Theoria Motus Abstracti. Ibid. 35.

Hermanni 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. Transf. 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. Neutoni 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. Muschenbroeck 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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DIRECTIONS for placing the PLATES.

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