of oxygen on bodies is greatly promoted in particular circumſtances. With the aſſiſtance of heat, almoſt all coloured bodies are decompoſed by means of oxygen. At the temperature of 448°, wheat flour is deprived of its white colour, becomes firſt brown, and then changes to black. The oxygen enters into combination with the hydrogen, one of the component parts of the vegetable matter, and in this ſtate it is driven off. The action of light produces effects ſimilar to thoſe of heat. A decompoſition of the colouring matter takes place by means of the light to which the body is expoſed; and one of its component parts combines with oxygen. The effects of light on the colour of wood have been long obſerved. Wood kept in the dark retains its natural appearance; but when it is expoſed to the light it becomes yellow, brown, or of ſome other ſhade. This effect is found to be ſubject to conſiderable variations in different kinds of wood, and bears ſome proportion to the intenſity of the light. If the ſolution of the green part of vegetables in alcohol, which is of a fine green colour, be expoſed to the light of the ſun, it very ſoon aſſumes an olive hue, and in the courſe of a few minutes it is entirely deprived of its colour. When the light is weak the change proceeds more ſlowly; and if it be kept in the dark no change whatever takes place; at leaſt it requires a great length of time. Light ſeems to favour the tendency to decompoſition in many bodies, by producing combinations of ſome of their conſtituent principles, as when water is formed by the union of oxygen and hydrogen, or carbonic acid by the union of carbone and oxygen. Some bodies even are deprived of the whole or part of their oxygen by the action of light. Oxymuriatic acid expoſed to the light, becomes common muriatic acid by loſing its oxygen; and the nitrate of ſilver becomes black by a partial decompoſition and loſs of its oxygen.

55. Such then ſeem to be the moſt general cauſes, the action of which produces changes in the colour of coloured bodies. It is either by the decompoſition of the ſubſtances, in conſequence of new compounds formed by the combination of ſome of the conſtituent parts; by ſome of theſe parts combining with oxygen; or by the addition or abſtraction of oxygen. And to ſuch changes colouring matters muſt be ſubjected from their compound nature; ſince they are moſt generally derived from animal or vegetable ſubſtances. The ſelection of ſuch ſubſtances as reſiſt the action of theſe cauſes, muſt therefore be an object of the greateſt importance in the art of dyeing. A colour too which is ſufficiently permanent ought to be ſuch as will reſiſt the action of acids, alkalies, ſoap, and other ſubſtances to which dyed cloth may be expoſed.

Method of proving the permanency of a colour.

56. There is a great difference in colours with regard to their power of reſiſting the action of air and light; and as it is in this that their permanency chiefly conſiſts, independent of their luſtre, it becomes an object of great importance, to be able to aſcertain by eaſy teſts the durability or goodneſs of any colour. In France, where the art of dyeing was more under the regulation of government than in other countries, and a diſtinction was eſtabliſhed by law between dyers of durable and fading colours, the means of aſcertaining the permanency of colours became of ſtill greater conſequence. For the dyer of fading colours was ſubject to puniſhment if he produced colours which were too permanent; ſo rigorous and capricious were the laws which regulated theſe matters. The obſervations of Mr Dufay on this ſubject laid the foundation of the regulations which were made to aſcertain this point. For this purpoſe he made experiments by dyeing wool of all colours, with all kinds of colouring matters; and ſetting entirely aſide the prejudices of the dyers, he collected moſt of the ſubſtances which he ſuppoſed might be employed in the art, and tried a great number of them, inveſtigating their good or bad qualities with great care.

Dufay's.

57. His firſt experiments were made on woollen yarn; but finding afterwards that pieces of white cloth were more ſuitable to the purpoſe, he employed them. And that he might diſtinguiſh between permanent and fading colours, he expoſed to the action of the ſun and air for the ſpace of twelve days, patterns of all colours which he had dyed with known ſubſtances. In this time durable colours were little injured, but thoſe which were of a fading nature were almoſt entirely obliterated. But as the action of the ſun might be leſs intenſe in cloudy weather, and thus the teſt would be leſs ſevere when that happened than during twelve days of bright ſunſhine; to obviate this inconvenience and uncertainty, he ſelected one of the worſt colours, that is, one on which the ſun had the greateſt effect in the ſame time. This colour ſerved as a ſtandard in his experiments; and whenever he expoſed ſtuffs to the air to prove the colour, he expoſed a piece of this ſtuff along with them. He did not calculate by the number of days, but by the change on the colour of the ſtandard ſtuff. For he kept the pattern expoſed to the air till it had loſt as much as the ſtandard would have done by the action of the ſun during twelve days in ſummer. He found from theſe experiments that it required four or five days longer in winter than in ſummer to produce the ſame effect.

58. But by this method of expoſure to the air he had another object in view. This was to diſcover the proper proof for each colour. By the application of this proof a ſtuff is tried whether its colour be permanent or not. The pattern for inſtance is boiled with alum, tartar, ſoap, vinegar, &c. and by the effect of theſe ſubſtances its quality is aſcertained. But from the component parts of the ſubſtances employed being then unknown, and the imperfect ſtate of chemical ſcience, theſe proofs muſt appear now to have been extremely precarious and inſufficient. Some which were applied, from their natural effects, deſtroyed good colours, and produced no effect whatever on bad colours.

59. As the method he employed may ſuggeſt the means of diſcovering others founded on more correct principles and more accurate knowledge of the ſubſtances whoſe action is inveſtigated, we ſhall mention the ingenious proceſs which he followed. Having obſerved the effects of air and light on each colour, whether it were a good or bad colour; he tried the ſame ſtuff with different proofs, and ſtopped as ſoon as he diſcovered one which produced the ſame effects as the air. He then noted the weight of the ingredients, the quantity of water, and the length of time; and thus he was certain of producing on a colour an effect ſimilar to that which the air would have produced, on the

ſuppoſition that it was dyed in the ſame way with his, as was the caſe in France where all the proceſſes were then regulated by law. In this way he was enabled to aſcertain the qualities of any colour, by making an analyſis of the ingredients of which it was compoſed. By means of the proofs which were invented by this ingenious chemiſt, as much of a colour which was not of a durable nature, could be diſcharged in a few minutes, as would be loſt by the action of the air and light in twelve or fifteen days. But as general rules framed for ſuch trials are liable to many exceptions, from different unavoidable cauſes, their application in many caſes may be conſidered as too ſevere. For inſtance, light colours require leſs active proofs than thoſe which are of a deeper dye, and are more loaded with colouring matter; in the latter caſe, a conſiderable proportion of colouring ſubſtance may be carried off without much viſible change on the colour; but in the former, by means of the ſame active teſt, the colour would be entirely obliterated. Every variety of ſhade, therefore, would have required a ſeparate proof. The ſun and the air muſt always be conſidered as the true teſt; and thoſe colours which undergo no change in a certain time by this expoſure, may be conſidered permanent colours, although they may be greatly changed by the application of proofs. Scarlet, which is dyed with cochineal alone, aſſumes a purple colour when tried by means of alum: but if ſcarlet be expoſed to the ſun, it loſes ſome of its brightneſs, and becomes of a deeper ſhade; but this ſhade is different from that which is produced by alum. In certain caſes then the ſame effect is not to be expected from the action of proofs and that of air and light.

Hellot's.

60. An experiment by Hellot is added as a farther illuſtration of a colour reſiſting the effects of expoſure to the air, and yet being deſtroyed by the action of other ſubſtances. Brazil wood, he mentions, like other woods loaded with colour, produces a fading dye. With this he prepared a red, much finer than madder reds, and as bright as thoſe made with kermes. This red was expoſed to the air for the two laſt months of the year 1740, in which much rain fell, and for the two firſt of 1741; and notwithſtanding the rain and bad weather, it was ſo far from loſing, that it gained body. Yet this red, ſo durable in the air, is incapable of reſiſting the trial by tartar. Colours then may be reckoned ſufficiently durable when they reſiſt the effects of the air, although they are decompoſed or deſtroyed by means of powerful chemical agents. From theſe obſervations, it is therefore obvious, that the only ſure mode of aſcertaining the permanency of colours, is by expoſing the dyed ſtuffs for a certain length of time to the action of light and air.

Berthollet's.

61. Berthollet * propoſes to employ the oxygenated muriatic acid as a quick and eaſy method of aſcertaining the degree of durability which a colour may poſſeſs; becauſe it acts like the air itſelf. When a trial is to be made on any piece of ſtuff, all that is neceſſary is to put a pattern of it into the acid, along with one of a ſtuff which is known to have been dyed properly. The relative power of reſiſting its action, which appears in the two patterns, becomes the teſt or meaſure of the quality of the colour. This liquor having a very powerful action on the colouring particles, muſt be employed in a very diluted ſtate. In the uſe of this proof, it is attended with the advantage of exhibiting nearly the ſhades and changes through which a ſtuff muſt paſs when it comes to be acted on by the air. Still, however, the ſame philoſopher adds, the oxygenated muriatic acid is not to be conſidered as an infallible teſt; entire confidence can only be placed in the reſults obtained by the action of the air and light.

Teſt for ſilk.

62. To prove the colours of ſilk, it has been thought ſufficient to expoſe them to heat in acetous acid or lemon juice; and thoſe colours which ſtand this teſt are conſidered as permanent. When the colours have been obtained from the woods or archil alone, they are reddened by means of a vegetable acid; but if the ſolution of tin has been uſed to dye with thoſe ſubſtances, the colour which has been prepared in an acid liquor ſuffers no change from vegetable acids. Thus the colour which is the leaſt expenſive in the preparation may be reckoned good by the teſt, although it will prove the leaſt permanent. For ſilk therefore, the oxygenated muriatic acid ſhould be employed; but more eſpecially expoſure to the air.

For dye ſtuffs.

63. It muſt appear an object of much importance to the dyer to be able to eſtimate the relative qualities of colouring ſubſtances of the ſame kind. The oxygenated muriatic acid may alſo be employed as a teſt for this purpoſe. By its uſe we may aſcertain the proportional quantity of colouring matter in thoſe ſubſtances, the nature of whoſe colouring particles is the ſame; as, for inſtance, when different parcels of indigo are to be compared together. In this caſe no foreign affinity can interrupt the action of the acid. And even if it ſhould happen, that any conſiderable difference exiſts in the nature of colouring particles ſuppoſed to be the ſame, the action of this acid, it is probable, would ſtill be a meaſure of their comparative goodneſs. If then it is propoſed to compare together two or more colouring ſubſtances of the ſame nature, and to aſcertain the relative quantity and quality of the colouring particles in each, all that is neceſſary is to compare the quantities of the ſame oxygenated muriatic acid which is required to produce the ſame degree of change in equal weights of each. For the qualities of theſe ſubſtances, or the quantities of colouring particles they contain, are directly proportional to the quantities of liquor required to produce the ſame effect on each. In conducting this experiment it is ſcarcely neceſſary to obſerve, that the colouring matter of each ſubſtance ſhould be diſſolved in a proper liquor, and that all the circumſtances attending the compariſon ſhould be as nearly as poſſible the ſame.

Indigo.

64. If different kinds of indigo are to be compared together, let an equal weight of each be carefully powdered, and introduced into ſeparate matraſſes with eight times their weight of concentrated ſulphuric acid, and let them remain for 24 hours in a heat of from 100° to 120° Fahrenheit. Each ſolution is then to be diluted with water, and filtered. What remains on the filter is to be collected, ground in a glaſs mortar, and again digeſted with a little more ſulphuric acid. Theſe laſt ſolutions are then to be diluted with equal quantities of water, filtered and added to its correſponding liquor. As much oxygenated muriatic acid is then to be added to each ſolution as will diſcharge the colour, or bring them to a ſhade of yellow;

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* *Elem. of Dyeing*, i. 186.

Of Mordants.

low: Thus the qualities of the different kinds of indigo may be aſcertained by the quantity of oxygenated muriatic acid which is required to diſcharge their colour.

65. The proceſs is more ſimple to compare the qualities of thoſe colouring matters which are ſoluble in water. To equal bulks of the decoction, containing the ſame weight of each ſubſtance, the oxygenated muriatic acid is added till they are all brought to the ſame ſhade; and the quality of the ſubſtance is proportionate to the quantity of acid required.

Chap. II. *Of Mordants.*

66. The term mordant, derived from the French word *mordre*, to bite or corrode, is applied to thoſe ſubſtances which are employed in dyeing, to facilitate or modify the combination of the colouring particles with the ſtuff. This name was given to theſe ſubſtances, from a ſuppoſed mechanical action which they produced on the ſubſtance to which the colour was communicated; and as no equivalent word has yet been propoſed, the original is retained in the Engliſh language.

Importance of mordants.

67. The knowledge of this claſs of ſubſtances is not leſs important in the art of dyeing than that of colouring matters themſelves, becauſe on their action depend the variety, brightneſs, and durability of colours. The action of mordants is undoubtedly owing to chemical changes, ſo that more extenſive obſervation and a complete knowledge of their effects, muſt greatly contribute to the improvement and perfection of the art of dyeing. It is by a new ſeries of attractions which are introduced by their action, that the colouring particles are combined with the ſtuff, and the qualities and degrees of the colours are affected.

68. A mordant is not always to be conſidered as a ſimple agent; for, of the different ingredients which enter into its compoſition, new combinations are ſometimes formed, ſo that the ſubſtances which are immediately employed, are not the direct agents in effecting the changes, but the new compounds which are produced.

Mode of application.

69. Mordants are applied in different ways, according to their nature, according to the nature of the colouring matter, and that of the ſtuff to be dyed. Sometimes they are mixed with the colouring particles, and ſometimes the ſtuffs to which the colour is to be communicated, are impregnated with them; and ſometimes both theſe proceſſes are combined. In ſome of the more complicated operations of dyeing, ſubſtances are ſucceſſively applied to ſtuffs in which the action of the laſt only produces the effect. In ſuch caſes, there is a gradual progreſs of combination; but it is only by the effect of the laſt compound which is formed, that the colour is evolved.

Illuſtrated.

70. The effects of mordants are well illuſtrated in many of the proceſſes which are followed in the art of printing linen; and for the illuſtration of theſe effects, we ſhall extract from Berthollet a ſhort account of ſome of theſe proceſſes. For linens to which it is propoſed to give different ſhades of red, the mordant employed is prepared by diſſolving in eight pounds of hot water, three pounds of alum, and one pound of acetate of lead, or ſugar of lead. To this ſolution two ounces of potaſh, and afterwards two ounces of powdered chalk, are to be added. Our chemical readers will readily perceive, that the firſt change which takes place is the decompoſition of the alum, by means of the acetate of lead. The oxide of lead combines with the acid of the alum, and forms an inſoluble ſalt, which is precipitated. The alumina which conſtitutes the baſe of the alum, unites with the acetous acid, and forms an acetate of alumina. The chalk and potaſh, according to Berthollet, ſerve to ſaturate the exceſs of acid; but it ſeems more probable that the addition of theſe ſubſtances is found neceſſary, on account of new decompoſitions which are effected by their action. Several advantages ariſe from the formation of the acetate of alumina, in the future changes which are to be effected. The alumina, or earthy baſis of this ſalt, is retained in combination with the acid, by a much weaker affinity than when combined with ſulphuric acid in the ſtate of alum. Its affinity being thus weakened, it is more eaſily decompoſed, and unites more readily with the ſtuff and colouring particles. Another advantage not leſs important is, that the effect of the acetous acid on the colouring matter being leſs powerful than the ſulphuric acid, the acid liquor which remains after the ſeparation of the alumina, does not produce ſuch hurtful effects. And beſides, as the acetate of alumina does not cryſtallize, the mordant which is thickened with ſtarch or gum, to prepare it for being applied to the block on which the deſign is engraved, retains the ſame uniform conſiſtence, which would not be the caſe if it contained alum, the latter being diſpoſed to cryſtallize.

71. Let us now trace the different ſteps of the operation in printing a piece of cloth. When it has been impregnated with the mordant, in the manner determined by the deſign, it is immerſed into a madder bath. Thus the whole of the cloth is coloured; but the colours are deeper on thoſe parts to which the mordant has been communicated; becauſe in thoſe parts the colouring particles of the madder have entered into combination with the alumina and the ſtuff forming a triple compound. The acetous acid ſeparated from its earthy baſis remains in the bath.

72. The effect of external agents on the colouring particles in this ſtate of combination is much leſs conſiderable than when they are in a ſeparate ſtate, or only combined with the ſtuff, without the intermediate action of another ſubſtance. It is on this property that the ſubſequent operations depend. Having been immerſed in the madder-bath, the cloth is afterwards boiled with bran, and expoſed to the open air by ſpreading it out on the graſs; and the ultimate repetition of theſe operations is continued till the ground is whitened. The colouring particles of the madder which have not come in contact with the alumina are completely changed by entering into new combinations; while thoſe which have united with it remain unaltered in conſequence of the ſtronger affinity, ſo that thoſe parts of the cloth which have been impregnated with the mordant, retain the colour and exhibit the deſign.

73. The decompoſition of the colouring particles by boiling the ſtuff with bran, and expoſure to the air, ſeems to be effected in a manner ſimilar to the deſtruction of the colouring matter of flax, and is to be accounted

counted for in the ſame way. In the proceſs of bleaching, indeed, alkaline ſubſtances are employed. But for the purpoſe of diſcharging the ſuperfluous colouring-matter from printed cloths, bran is preferred as a ſubſtitute; becauſe part of the colouring-matter, even when fixed by alumina, would be deſtroyed by the ſtronger action of alkalies; but as the action of the bran is much weaker, it affects only the colouring particles which have not come in contact with the alumina, and which by the action of the air are diſpoſed to undergo a more eaſy ſolution.

74. Let us take another example with a different mordant. If, inſtead of alum, a ſolution of iron, as the acetate of iron, be employed, ſimilar phenomena are exhibited. The ſolution of iron is decompoſed by the particles of colouring-matter, and a triple compound is thus formed of the colouring-matter, the oxide of iron, and the ſtuff. But when this mordant is employed, a great variety of ſhades from brown to a deep black are obtained by the uſe of madder; and by a combination of alum and iron, the colours produced are of a mixed nature, inclining on the one hand to red, and to black on the other. And if another ſubſtance, as dyers-weed, be ſubſtituted for the madder, other colours are obtained. Indeed the great variety of ſhades which are communicated to printed ſtuffs are derived from the colouring-matter of madder, dyers-weed, and indigo, fixed by alumina or the oxide of iron as mordants.

75. The different ſubſtances which enter into the compoſition of a mordant remain in combination till a new action is induced by the application of another ſubſtance. Thus, the affinity of the ſtuff for one of their conſtituent parts produces a decompoſition and new combinations. But even this effect is ſometimes incomplete, or does not at all take place without the action of another affinity, namely, that of the colouring-particles. We have an example of this in the mixture of alum and tartar, which is one of the moſt common mordants in the dyeing of wool.

76. The following experiments were made by Berthollet, to aſcertain the effects of theſe ſubſtances as mordants. He diſſolved equal weights of alum and of tartar; and he found that the ſolubility of the tartar was increaſed by the mixture. By evaporation and a ſecond cryſtallization, the two ſalts were ſeparated, ſo that no decompoſition had taken place. Half an ounce of alum and one ounce of wool were boiled together for an hour, a precipitate was formed, which being carefully waſhed, was found to conſiſt of filaments of wool incruſted with earth. To this ſulphuric acid was added, and the ſolution being evaporated to dryneſs, cryſtals of alum were obtained, with the ſeparation of ſome particles of carbonaceous matter. The liquid in which the wool had been boiled being evaporated, yielded only a few grains of alum; what remained would not cryſtallize. This being rediſſolved and precipitated by means of an alkali, the alumina which was thrown down was of a ſlate colour, became black when placed on red-hot coals, and emitted alkaline vapours. In this experiment it appears that the alum was decompoſed by the wool, and part of the alumina had combined with its moſt detached filaments which were leaſt retained by the force of aggregation; that part of its animal ſubſtance had been diſſolved and precipitated by the alkali from the triple compound.

77. The ſame experiment was repeated with half an ounce of alum and two drams of tartar; but no precipitation followed. A ſmall portion of the tartar, and ſome irregular cryſtals of alum were obtained by cryſtallization: the remainder refuſed to cryſtallize; but being diluted with water, precipitated by potaſh, and evaporated, it yielded a ſalt which burned like tartar. The wool which was boiled with the alum had a harſh feel; but the other retained all its ſoftneſs. The firſt, after being ſubjected to the proceſs of maddering, had a duller and lighter tint; but the colour of the latter was fuller and brighter.

78. In the firſt of theſe experiments the wool had effected a decompoſition of the alum, had united with part of the alumina; and even part of the alum which retained its alumina had diſſolved ſome portion of the animal matter. In the ſecond experiment it appears, that the tartar and alum, between which there ſeems to exiſt a balance of affinities, can only act on each other by the intermediate action of the wool. The principal uſe of the tartar ſeems to be to moderate the action of the alum on the wool, by which it is injured. In the aluming of ſilk and thread, whoſe action on alum is leſs powerful than that of wool, tartar is not found requiſite.

79. Whatever be the mode adopted in aluming, or whatever be the chemical changes which are produced, its final effect is the union of the alumina with the ſtuff. At firſt this combination has probably been incomplete, and a partial ſeparation only of the acids has taken place; but it is perfected after the cloth has been boiled with the madder, as appeared in the caſe of printed ſtuffs *.

Subſtances uſed as mordants.

80. The principal ſubſtances which are employed for the purpoſes of mordants in the proceſſes of dyeing, are earths, metallic oxides, and ſome aſtringent matters. Alumina, which is now one of the moſt important, and in moſt general uſe, was very early employed as a mordant. This earth, as has been proved by direct experiment, and which is ſtill farther confirmed by daily practice and obſervation, is uſeful in the art of dyeing, in conſequence of the affinity which exiſts between it, the ſtuffs to be dyed, and the colouring matter. The affinity of alumina for animal matters, as wool and ſilk, is much ſtronger than that for vegetable productions, as cotton and linen; and hence the difference in the facility of fixing the colours on theſe different ſubſtances, and in their durability.

Alum.

81. When alumina is employed as a mordant, it is always in a ſtate of combination, either in that of alum, which is the ſulphate of alumina and potaſh, or united with the acetous acid, forming the acetate of alumina. Alum was employed at a very early period as a mordant. It was uſed by the ancients as it was found native, and therefore far from being in a ſtate of purity. But as the nature of the conſtituent parts of alum was long unknown, its uſe in dyeing, as well as that of mordants in general, can only be ranked among the diſcoveries of modern chemiſtry. Alumina is alſo employed for a ſimilar purpoſe, in combination with the acetous acid. This combination of alumina ſeems to have been firſt introduced about the beginning of the 18th century, and its introduction, like other valuable improvements,

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* *Elem. of Dyeing*, i 34.

improvements, was owing to accident. It was firſt employed by the callico-printers; but at what time, or by whom it was firſt uſed, is not exactly known. In one of the earlieſt recipes for preparing the mixtures employed as mordants in callico-printing, which Dr Bancroft, in his inveſtigation of this ſubject, informs us he examined, the ſubſtances directed to be uſed are alum, ſal ammoniac, ſalt petre, red orpiment, and kelp; and theſe were to be mixed with water. In another, which he obſerves probably followed this, theſe ingredients were to be diſſolved in vinegar. Sugar-of-lead was afterwards added in ſmall quantity, and among a great variety of other ſubſtances which were employed at different times, litharge and white-lead came into uſe. In caſes where vinegar was employed as the ſolvent, after different decompoſitions had taken place, a portion of acetate of alumina was formed, and the uſe of it was found to be followed with good effects. The quantity of ſugar-of-lead, from obſerving the advantages derived from it, was gradually increaſed, and the employment of many of the other ſubſtances which were found by experience to be uſeleſs, was omitted. As the introduction of acetate of alumina was at firſt owing to chance, and as the changes and decompoſitions which took place in its formation were entirely unknown, it is not to be wondered at that the diſcovery or invention of this ſubſtance as a mordant, ſhould not be diſtinctly aſcertained.

82. The uſual method of preparing the acetate of alumina is by pouring acetate of lead into a ſolution of alum. Both the ſalts are decompoſed, by an exchange of their conſtituent parts. The ſulphuric acid and the lead having a ſtronger affinity than the ſulphuric acid and the alumina, combine together, and fall to the bottom in the form of an inſoluble powder. The alumina at the ſame time enters into combination with the acetous acid, and remains diſſolved in the liquid. But the application and effects of this ſubſtance in dyeing have been fully illuſtrated in treating of mordants in general.

Lime.

83. Lime is the only earth, beſides alumina, which is employed in dyeing. The affinity of lime for cloth is ſufficiently ſtrong; it is, however, found to anſwer the purpoſe of a mordant leſs perfectly than alumina, on account of the colour, which is not ſo good. It is employed, either in the ſtate of lime water, or in that of ſulphate of lime diſſolved in water.

Metallic oxides.

84. Metallic oxides have a ſtrong affinity for animal ſubſtances. They have alſo ſo great an attraction for many colouring matters, that they ſeparate from the acids with which they are combined, and are precipitated in combination with the colouring matters. In conſequence of theſe different affinities, metallic oxides are of great importance in dyeing, and hence they were early applied in that art, and are now extenſively uſed. But beſides the affinity of theſe oxides for the colouring particles, and for animal ſubſtances, their ſolutions in acids poſſeſs properties by which they are more or leſs fit to be employed as mordants. Thus, thoſe oxides which eaſily part with their acids, ſuch as that of tin, are capable of entering into combination with animal ſubſtances, without the aid of colouring particles. All that is neceſſary is to impregnate the wool or the ſilk with a ſolution of tin. Some metallic ſubſtances yield only in combination, a white and colourleſs baſis; but there are others which, by means of their own colour, produce modifications on the peculiar colour of the colouring particles. But the effects of many metallic oxides are extremely different, according to the proportion of oxygen with which they are combined; and this proportion is variable.

85. The affinity of metallic oxides for vegetable matters is conſiderably weaker than that which they have for animal ſubſtances. Metallic ſolutions, therefore, are found not to anſwer ſo well as mordants for colours in dyeing cotton or linen. Iron, indeed, is an exception, the oxide of which, it is well known, has a ſtrong affinity for vegetable ſubſtances. Iron moulds on cotton or linen are owing to a combination of the oxide of iron with the vegetable matter.

86. Although almoſt all metallic oxides have an affinity for animal and vegetable matters, and might therefore be employed as mordants, yet two only, either becauſe they are found to anſwer the purpoſe better, or becauſe they are cheaper, are uſed to any extent. Theſe are the oxides of tin and of iron.

Oxide of tin.

87. The uſe of the oxide of tin ſeems to have been firſt diſcovered by a German chemiſt of the name of Kuſter or Kuffler. Obſerving the effects of a ſolution of tin in nitric acid, in giving a more vivid colour to ſtuffs dyed with cochineal, he was led to the diſcovery of the method of producing what has ſince been denominated *cochineal ſcarlet*. This diſcovery has been aſcribed by others to Drebel, a Dutch chemiſt: and Macquer, who is of this opinion, ſuppoſes that the firſt ſolutions of tin were made with nitro-muriatic acid; but Dr Bancroft thinks that there is good reaſon to believe, that nitric acid only was uſed for ſome years for this purpoſe. According to Mr Delaval, the uſe of tin in dyeing was known to the ancients; and he ſuppoſes that the tin which the Phœnicians carried from Britain, was employed in this way, becauſe he thinks that it is neceſſary to the production of red colours, whether from animal or vegetable matter. Dr Bancroft, however, has proved, that this opinion is founded in miſtake.

88. About the year 1543, Kuſter brought his ſecret to London, and it appears that it was firſt employed for this purpoſe at Bow. Hence the ſcarlet colour thus produced was denominated in this country the *Bow dye*. It ſeems too, that this mode of dyeing ſcarlet was very early introduced into Holland. A Frenchman of the name of Gobelins, received an account of the proceſs from a Flemiſh painter called Kloeck, to whom it had been communicated by Kuſter himſelf, and eſtabliſhed it in France. Hence the Bow dye of England was known in other parts of Europe under the names of Dutch ſcarlet, ſcarlet of the Gobelins.

89. We have mentioned above, that the effects of metallic oxides as mordants in dyeing, depend on the different proportions of oxygen with which they may be combined. Thus, there are two oxides of tin containing different proportions of oxygen; the one contains 30 parts of oxygen in the 100, and the other contains 40. The oxide having the ſmaller proportion of oxygen, by being expoſed to the air combines with a new portion of oxygen, and is ſoon converted into the oxide with the greater proportion, or the white oxide. It is

this laſt which is the mordant, for if the other were applied to the ſtuff, it would ſoon be converted into the white oxide, by combining with an additional portion of oxygen.

90. Tin was firſt uſed as a mordant diſſolved in nitric acid; but this preparation was found not to anſwer well, becauſe the nitric acid readily converted the tin to the ſtate of white oxide, in which ſtate it is incapable of diſſolving it. A precipitation of the tin took place, to prevent which, different ſubſtances were added, as common ſalt, or ſal ammoniac; and thus a nitro-muriatic acid was produced, by which means the white oxide of tin was held in ſolution. It appears, however, that it was a conſiderable time before this method came into general uſe. Hellot, in an account of the proceſs employed in his time for dyeing ſcarlet at Carcaſſonne, mentions that the tin was diſſolved only in diluted nitric acid, adding that a Mr Baron was the firſt in that city who employed nitro-muriatic acid for the ſolution of tin, to prevent the precipitation of the oxide.

Preparation.

91. The ordinary ſolution of tin is made with that ſpecies of nitric acid called ſingle aquafortis, and as it is uſually prepared, it is found capable of diſſolving about $\frac{1}{8}$ part of its weight of granulated tin. To each pound of aquafortis from one to two ounces of ſea ſalt, or, what is deemed preferable by ſome, of ſal ammoniac, are added. The acid is commonly diluted with a little water. The ſolutions which are made moſt ſlowly, and with the leaſt ſeparation of vapours, are found to ſucceed beſt. Two ounces of granulated tin are uſually allowed for each pound of aquafortis; and the metal ſhould be added at different times, to moderate the rapidity of the ſolution. The water added to the acid ſhould be weighed or meaſured, that a ſolution of the ſame ſtrength may be always obtained. Eighteen or 20 pounds of this ſolution (A) are required to give a full cochineal ſcarlet to 100 pounds of woollen cloth.

92. But in the dyeing of ſcarlet, according to the ordinary proceſs, a quantity of tartar is diſſolved in the water, along with the nitromuriate of tin; and if the tartar be employed in ſufficient quantity, the mordant is not to be conſidered as a nitromuriate of tin, but a tartrate or combination of tin with tartaric acid, in conſequence of the decompoſition which takes place, when theſe ſubſtances are brought to act on each other; for the nitromuriatic acid enters into combination with the potaſh or the tartar, while the acid of the tartar forms a compound with the oxide of tin.

93. It has been propoſed by Hauſſman to employ the acetate of tin as a mordant for cotton and linen, inſtead of the nitromuriate. The acetate of tin is prepared by mixing together acetate of lead and nitromuriate of tin; and as the affinity between metallic oxides and vegetable ſubſtances is leſs powerful than the affinity between theſe oxides and animal matters, this mordant has been found preferable for cotton and linen ſtuffs; for the affinity of the oxide of tin for the acetous acid being weaker than for the nitromuriatic acid, it is more eaſily decompoſed.

94. Dr Bancroft * tried the ſolution of tin in ſulphuric acid, but found that it would not anſwer, on account of its deſtructive action on the cochineal colour; but he found afterwards, that, by the uſe of muriatic acid combined with $\frac{1}{4}$ its weight of ſulphuric acid, good effects were obtained. The proportions which he employed were about 14 ounces of tin in a mixture of 2 pounds of ſulphuric acid of the ordinary ſtrength, with about 3 pounds of muriatic acid. This preparation may be made in the cold; but the ſolution is very rapidly promoted with a ſand heat. The ſolution of tin made in theſe proportions, Dr Bancroft obſerves, is perfectly tranſparent and colourleſs; and in the ſpace of three years, during which time he kept a ſolution of it, no precipitation had taken place. It produces, he adds, full twice as much effect as the dyer's *ſpirit*, or nitromuriatic ſolution of tin, and at leſs than one-third of the expence.

Oxide of Iron.

95. Iron exiſts in two ſtates of combination with oxygen. In the ſtate of green oxide it contains the ſmaller proportion of oxygen, and in that of red oxide the greater proportion. In the laſt ſtate it can only be employed as a mordant in dyeing; for if it be applied in the ſtate of green oxide, in conſequence of its ſtrong affinity for oxygen, it attracts it from the atmoſphere, and is ſoon converted into red oxide. The difficulty of removing iron ſpots or mould from cotton or linen ſhows with what force of affinity the red oxide of iron adheres to cloth. Iron is employed as a mordant in two ſtates of combination, either in that of ſulphate or acetate of iron. The ſulphate of iron is generally employed for wool. The ſtuff is immerſed in the ſolution of the ſalt in water. In this ſtate it may be alſo uſed for cotton; but it is more commonly preferred in the ſtate of acetate of iron. This is the combination of iron with the acetous acid, and it is uſually prepared by diſſolving iron in vinegar or ſour beer; and the longer it is retained in the ſolution, it is found to act more powerfully as a mordant, becauſe it is then in a ſtate of more complete oxidation.

96. Some other ſaline bodies are alſo employed as mordants, to facilitate the combination of the colouring matter with the cloth, or to produce greater variety of ſhades of colour. Among theſe ſubſtances may be mentioned common ſalt, ſal ammoniac, acetate of lead, ſulphate and acetate of copper, ſulphate of zinc.

Animal and vegetable matters.

97. Beſides the mordants obtained from the claſs of ſalts, vegetable and animal ſubſtances alſo ſerve a ſimilar purpoſe. In the proceſs for dyeing the Turkey red, which will be afterwards deſcribed, the cotton ſtuffs ſhould be impregnated with an animal ſubſtance, as oil; and the aſtringent principle is often employed as a medium of combination between colouring particles and ſtuffs. Tan, or the aſtringent principle, having a ſtrong affinity for cloth, is found extremely uſeful as a mordant. It is commonly prepared by infuſing nut-galls in water. The cloth is immerſed in this ſolution, and allowed to remain till it is ſufficiently impregnated with the tan. Sumach, which is the ſhoots of the *Rhus coriaria* Lin. a ſhrub, which grows in the ſouthern parts of

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* *Philoſ. of Perm. Col.* 289.

(A) This ſolution is called *ſpirit* by the dyers in this country.

of Europe, is often uſed and prepared in the ſame way as the nut-galls.

Effects of mordants on the colour.

98. Mordants have a very conſiderable effect on the colour; and, by varying the mordant, very different colours, and a great variety of ſhades, may be obtained from the ſame colouring matter. Some mordants themſelves may be conſidered as communicating a colour without the addition of any colouring ſubſtance; and although, when the latter is added, a new ſet of affinities is brought into action, yet there is little doubt that the mordant alſo has a conſiderable ſhare in fixing the ſhades of colour. Let us take an example in dyeing with cochineal. When the aluminous mordant is employed, the colour produced is crimſon; but when the oxide of iron is ſubſtituted for the alumina, the colour obtained is black. This effects is obviouſly produced by a change in the action of the affinities between the colouring matter and the mordant, and the colouring matter and light. In the uſe of mordants, therefore, it is neceſſary to attend to their combined effects with the colouring matter employed, and to be able to communicate particular colours to ſtuffs with any degree of certainty, to know the amount of that effect.

99. Even in the mode of applying mordants, the variety of ſhades may be greatly multiplied. Different effects, for inſtance, are produced by previouſly impregnating the ſtuff with the mordant, or by mixing it with the bath. Different effects alſo ariſe from uſing heat, or, as the ſtuff is more or leſs rapidly dried; and this muſt appear to be the caſe, if we conſider the different affinities which are in action, and the change on the action of theſe affinities in theſe different circumſtances, as well as in others which can ſcarcely be appreciated. The combination of theſe ſubſtances which have an affinity for the ſtuff, and the decompoſitions which are the reſult of that combination, are greatly facilitated by the evaporation of the water or other liquid which held theſe ſubſtances in ſolution; becauſe by its affinity, which is oppoſed to the action of the affinity between theſe ſubſtances and the ſtuff, the affinity of the latter produces a more limited effect. But in dyeing, the proceſs ſhould proceed ſlowly, that the ſubſtances may not be ſeparated before their mutual affinities have begun to operate.

100. Conſiderable differences muſt be obſerved in the mode of employing the mordant, as the force of affinity between the ſtuff and the colouring matter is greater or leſs. When this affinity is ſtrong, the mordant and the colouring ſubſtance may be mixed together; the compound thus formed, immediately enters into combination with the ſtuff. But if the affinity between the ſtuff and the colouring particles be weak, the compound formed of the latter and the mordant may ſeparate, and a precipitation take place, before it can be attached to the ſtuff; and hence it is in theſe caſes, that the mordant which is to ſerve as the medium of union between the ſtuff and the colouring matter, muſt be combined with the former, before the application of the latter. It is from theſe differences that different proceſſes muſt be followed in fixing colouring matters on animal and vegetable productions; as for inſtance, in dyeing wool or ſilk black, or with cochineal.

101. In eſtimating the effects of mordants, and in judging of the moſt advantageous manner of applying them, it is neceſſary to attend to the combinations which may be formed, either by the action of the ingredients of which they are compoſed, or, by that of the colouring matter and the ſtuff. It is neceſſary alſo, to take into conſideration the circumſtances which may tend to bring about theſe combinations with more or leſs rapidity, or that may render them more or leſs perfect. The action which the liquor in which the ſtuff is immerſed may have, either on its colour or texture, muſt alſo be conſidered; and to be able accurately to judge of the extent of this action, we muſt know the proportions of the principles of which the mordant is compoſed; which of theſe principles remains in an uncombined ſtate in the liquor, and the proportion or quantity which is thus ſeparated.

CHAP. III. *Of the Nature and Properties of the Subſtances to which Colours are communicated in the Proceſſes of Dyeing.*

102. IN the more limited ſenſe to which we have here reſtricted the art of dyeing, the ſubſtances to which colours are uſually communicated by means of this art, are wool, ſilk, cotton, flax, and hemp. Of theſe, the two firſt are animal ſubſtances, and the three latter are derived from the vegetable kingdom. Theſe two claſſes of bodies preſent ſtriking differences, not only in ſtructure, but alſo in their compoſition and chemical properties.

Difference between animal and vegetable matters.

103. Animal ſubſtances are diſtinguiſhed from thoſe which have a vegetable origin, by the nature of their conſtituent parts. The former contain a large proportion of azote, which exiſts ſparingly in the latter. Hydrogen, or the baſe of hydrogen gas or inflammable air, is found in greater abundance in animal matters, than in vegetable productions. In the diſtillation of animal and vegetable ſubſtances, the difference of their conſtituent parts is not leſs remarkable. The former afford a large proportion of ammonia, or volatile alkali; the latter yield very little, and ſometimes give out an acid ſubſtance. Animal matters afford much oil, while vegetable ſubſtances ſometimes do not afford it in any perceptible quantity. From the nature of their component parts, animal ſubſtances produce a bright flame in burning; and their combuſtion is accompanied with a penetrating odour, which is owing to the formation and emiſſion of ammonia and oil. Animal matters run rapidly into the putrefactive proceſs, while vegetable ſubſtances more ſlowly undergo the changes which are induced by the vinous or acetous fermentation.

104. The conſtituent principles of animal ſubſtances have a ſtronger tendency than thoſe which enter into the compoſition of vegetable matters, to aſſume the elaſtic form. On this account the coheſive force exiſting between the particles of the former is inferior to that of the particles of the latter. Hence animal matters are more diſpoſed to combine with other ſubſtances, more liable to be deſtroyed by different agents, and to enter into combination with colouring particles. Thus, animal ſubſtances are deſtroyed by the cauſtic fixed alkalies, and they are decompoſed by the nitric and ſul-

phuric acids. The action of acids and alkalies on ſilk is leſs powerful than upon wool, and it is leſs diſpoſed to combine with the particles of colouring matter. In this reſpect it bears ſome reſemblance to vegetable ſubſtances; but on vegetable matters, the action of alkalies and acids is leſs powerful than on animal ſubſtances; and the action of acids is more feeble on cotton than on flax or hemp. It is even decompoſed with conſiderable difficulty by means of nitric acid.

In the four following ſections, we ſhall conſider the peculiarities of theſe ſubſtances at greater length.

SECT. I. *Of Wool.*

Structure. 105. Wool, which is well known as the covering of ſheep, derives its value from the length and fineneſs of its filaments. The filaments of wool are conſiderably elaſtic, for they may be drawn out beyond their uſual length, and when the force is removed, they recover it again. The ſurface of the filaments of wool or hair is not perfectly ſmooth; for although no roughneſs or inequality can be diſcovered by the microſcope, yet they ſeem to be formed of ſmall laminæ placed over each other, in a ſlanting direction, from the root of the filament towards its point, reſembling the arrangement of the ſcales of a fiſh, which cover each other from the head of the animal to its tail; or perhaps they conſiſt of zones placed over each other, as is obſerved in the horns of animals. This peculiarity of ſtructure of the filaments of hair and wool is proved by a ſimple experiment. If a hair be laid hold of by the root in one hand, and drawn between the fingers of the other hand, from the root towards the point, ſcarcely any friction or reſiſtance is perceived, and no noiſe is heard; but if it be graſped by the point, and paſſed in the ſame manner between the fingers from the point towards the root, a reſiſtance is felt, and a tremulous motion is perceptible to the touch, while the ear is ſenſible to a ſlight noiſe. Thus it appears, that the texture of the ſurface of hair or wool is not the ſame from the root towards the point, as it is from the point towards the root. This is farther confirmed by another experiment. If a hair be held between the thumb and forefinger, and they are rubbed againſt each other in the longitudinal direction of the hair, it acquires a progreſſive motion towards the root. This effect depends not on the nature of the ſkin of the finger, or on its texture, for if the hair be turned, and the point placed where the root formerly was, the motion is reverſed, that is, it will ſtill be towards the root.

Felting. 106. On this peculiarity of ſtructure, which was obſerved by M. Monge, depend the proceſſes of felting and fulling, to which hair and wool are ſubjected, for different purpoſes. In the proceſs of felting the flocculi of wool are ſtruck with the ſtring of the bow, by which the filaments are ſeparately detached, and diſperſed in the air. Theſe filaments fall back on each other in all directions on the table, and when a layer of a certain thickneſs is formed, they are covered with a cloth, on which the workman preſſes with his hands in all parts. By this preſſure the filaments of wool are brought nearer to each other; the points of contact are multiplied; the progreſſive motion towards the root is produced by the agitation; the filaments entangle each other; and the laminæ of each filament, taking hold of thoſe of the other filaments, which are in an oppoſite direction, the whole is retained in the ſtate of cloſe contexture.

Fulling. 107. Connected with this operation is that of fulling. The roughneſs on the ſurface of the filaments of wool, and their tendency to acquire a progreſſive motion towards the root, produce conſiderable inconvenience in the operations of ſpinning and weaving. Theſe inconveniences are obviated by covering the filaments with a coat of oil, which fills up the cavities, and renders the aſperities leſs ſenſible. When theſe operations are finiſhed, the ſtuff muſt be freed from the oil, which would prevent it from taking the colour with which it is to be dyed. For this purpoſe it is taken to the fulling-mill, where it is beaten with large beetles, in a trough of water, through which clay has been diffuſed. The clay unites with the oil, which being thus rendered ſoluble in the water, is carried off by freſh portions of water, conveyed to it by proper apparatus. In this way the ſtuff is ſcoured; but this is not the ſole object of the operation. By the alternate preſſure of the beetles, an effect ſimilar to that of the hands in the operation of felting, is produced. The filaments compoſing a thread of warp or woof, acquire a progreſſive motion, are entangled with the filaments of the adjoining threads; thoſe of the latter into the next, and ſo on, till the whole threads are felted together. The ſtuff is now contracted in all its dimenſions, and participating both of the nature of cloth and of felt, may be cut without being ſubjected to ravel; and when employed to make a garment, requires no hemming. In a common woollen ſtocking web, after this operation, the ſtitches, when one happens to ſlip, are now no longer ſubject to run, and the threads of the warp and woof being leſs diſtinct from each other, the whole ſtuff is thickened, and forms a warmer clothing.

Importance of wool. 108. The various manufactures, of which wool conſtitutes the baſis, are juſtly regarded among the moſt important to man in civilized ſociety. Accordingly, the production of fine wool, and the cauſes which retard or improve the breed of ſheep from which it is obtained, have greatly occupied the attention of economiſts and philoſophers in our own, as well as in other countries. The wool of different breeds of ſheep, in different countries, it is well known, poſſeſſes very different qualities, both with regard to the fineneſs of the filament, and the colour. Some is of a white, or yellow, and ſome of a reddiſh, and black colour. Excepting the wool of the breed of ſheep in Andaluſia, the Spaniſh wool was formerly all of a browniſh black colour. This was preferred by the native Spaniards; and even at this day, the dreſs of ſome religious orders in Roman Catholic countries, conſiſts of cloth manufactured from this wool, and retaining its natural colour. But for the purpoſes of dyeing, white wool is now always preferred, becauſe it is found ſuſceptible of receiving better and more durable colours.

Scouring. 109. Wool is naturally covered with a kind of greaſe or oil, which is found to preſerve it from inſects or moths, and on this account this greaſy matter is not removed, or the wool is not ſcoured till it is to be dyed or ſpun (A). The proceſs for ſcouring wool is the following. It is put for about a quarter of an hour into a kettle, with a ſufficient quantity of water, to which a fourth part of putrid urine has been added. It is then heated to ſuch a degree as the hand can bear, occaſionally ſtirred, and after being taken out, is allowed to drain. It is then put into a baſket, and expoſed to a ſtream of running water, and moved about till the greaſe is ſo completely ſeparated, that it no longer renders the water turbid. After being drained, it is ſometimes found to loſe by this operation above one-fifth of its weight. It is almoſt unneceſſary to obſerve, that the more carefully and completely this proceſs is performed, the better the wool is fitted to receive the colouring matter. Our chemical readers will readily perceive the nature of the changes which are effected in this proceſs of ſcouring. The ammonia, or volatile alkali, which exiſts in the urine, combines with the oil of the wool, and forms a ſoap, which being ſoluble in water, is diſſolved, and carried off.

Dyeing.

110. Wool is either dyed in the fleece, or after it is ſpun into threads, or when it has been manufactured into cloth. For the purpoſe of forming cloths of mixed colours, it is dyed before it is ſpun; for the purpoſes of tapeſtry, it is dyed in the ſtate of thread; but moſt commonly it is ſubjected to this proceſs after it has been manufactured into cloth. In theſe different ſtates, the quantity of colouring matter which is taken up is very different. The proportion is largeſt when it is dyed in the fleece, becauſe then the filaments being more ſeparated, a greater ſurface is expoſed to the action of the colouring particles. For a ſimilar reaſon the quantity of colouring matter taken up is greater when in the ſtate of thread or yarn, than when it is formed into cloth. But cloths themſelves muſt vary greatly in this reſpect, according to their different qualities. Their different degrees of fineneſs, or cloſeneſs of texture, will produce conſiderable variations; and beſides, the difference in the quantity and dimenſions of the ſubſtances to be dyed, the different qualities of the ingredients employed in the proceſs, and the different circumſtances in which it is performed, ſhould be a caution againſt truſting to preciſe quantities, regulated by weight or meaſure, which are recommended according to general rules. According to the fineneſs of the texture of the wool, and the nature of the colouring matter employed, it is found to be more or leſs penetrated with this matter. The coarſe wool from the thighs and tails of ſome ſheep, receives colours with difficulty, and the fineſt cloth is never completely penetrated with the ſcarlet dye. The interior of the cloth appears always when cut, of a lighter ſhade, and ſometimes even white.

Sect. II. *Of Silk.*

Origin.

111. Silk, which forms the baſis of one of the richeſt and moſt ſplendid parts of dreſs, among the wealthy and luxurious, in civilized ſociety, is the production of different ſpecies of inſects. The *phalæna bombyx*, or ſilk-worm, which is a native of China, attracted the attention of mankind in that country, from the earlieſt ages. The honour of having firſt collected and prepared ſilk from the cocoons or balls in which it is wound up by the inſect, during its metamorphoſis, is aſcribed by the Chineſe hiſtorians, to the wife of an emperor. The *phalæna atlas*, Lin. which is alſo a native of China, is ſaid to form larger cocoons, and to yield a ſtronger ſilk. The ſilk-worm was firſt carried from China to Hindoſtan, and afterwards to Perſia. Silk ſeems not to have been known to the Greeks or Romans till the time of Auguſtus. Its nature and origin were little underſtood, and for many ages it was ſo ſcarce, that it could only be purchaſed at a price which was equal to its weight in gold. The emperor Aurelian, it is ſaid, from a principle of economy, reſiſted the urgent ſolicitations of his empreſs, who wiſhed to have a ſilken robe, alleging the extravagance of the expence. About the middle of the ſixth century, two monks returned from India to Conſtantinople, and brought with them a conſiderable number of ſilk-worms, with inſtructions for managing and breeding them, as well as for collecting, preparing, and manufacturing the ſilk. Eſtabliſhments were thus formed at Corinth, Athens, and other parts of Greece. The cruſades, which greatly contributed to the diffuſion of different kinds of knowledge, by the intercourſe which took place between different countries, proved uſeful in diſſeminating the knowledge of rearing the ſilk-worm, and preparing and manufacturing its valuable productions. Roger, king of Sicily, about the year 1130, returning from one of theſe frantic expeditions, brought with him from Athens and Corinth, ſeveral priſoners, who were acquainted with the management of ſilk-worms, and the manufacturing of ſilk. Under their ſuperintendance, manufactories were eſtabliſhed at Palermo and Calabria in Sicily. This example was ſoon adopted, and followed in different parts of Italy and Spain. In the time of James I. an attempt was made to eſtabliſh the ſilk-worm in England. For this purpoſe the culture of the mulberry-tree on which the inſects feed, was ſtrongly recommended by that prince to his ſubjects; but the attempts which were made have been hitherto unſucceſsful.

Scouring.

112. The fibres of ſilk are covered with a coating or natural varniſh of a gummy nature. To this are aſcribed its ſtiffneſs and elaſticity. Beſides this varniſh, the ſilk which is uſually met with in Europe is impregnated with a ſubſtance of a yellow colour, and for moſt of the purpoſes to which ſilk is applied, it is neceſſary that it ſhould be deprived, both of the varniſh and of the colouring matter. On this account it muſt be ſubjected to the operation of ſcouring; but for ſilks which are to be dyed, this proceſs ſhould not be carried ſo far as for thoſe which are merely to be whitened; and different colours, it is obſerved, require different degrees of this operation. The quantity of ſoap conſtitutes the chief difference. A hundred pounds of ſilk boiled in a ſolution of 20 lbs. of ſoap for three or four hours, adding new portions of water during the evaporation, are ſufficiently prepared for receiving common

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(A) According to an obſervation of Reaumur, rubbing any ſtuff with greaſy wool, is ſufficient to preſerve it from moths.

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colours. For blue colours, the proportion of ſoap muſt be increaſed; and ſcarlet, cherry-colour, &c. require ſtill a greater proportion, for the ground muſt be whiter for theſe colours.

Proceſs, when employed white.

113. Silk which is to be employed white, muſt undergo three operations. In the firſt the hanks are immerſed in a hot but not boiling ſolution of 30 lbs. of ſoap to 100 of ſilk. When the immerſed part is freed from its gum, which is known by its whiteneſs, the hanks are ſhaken over, as the workmen term it, ſo that the part which was not previouſly immerſed may undergo the ſame operation. They are then wrung out as the proceſs is completed. In the ſecond operation the ſilk is put into bags of coarſe cloth, each bag containing 20 or 30 lbs. Theſe bags are boiled for an hour and a half, in a ſolution of ſoap prepared as before, but with a ſmaller proportion of ſoap; and that they may not receive too much heat, by touching the bottom of the kettle, they muſt be conſtantly ſtirred during the operation. The object of the third operation is to communicate to the ſilk different ſhades, to render the white more agreeable. Theſe are known by different names, as China-white, ſilver-white, azure-white, or thread-white. For this purpoſe a ſolution of ſoap is alſo prepared, of which the proper degree of ſtrength is aſcertained by its manner of frothing by agitation. For the China-white, which is required to have a ſlight tinge of red, a ſmall quantity of anatto is added, and the ſilk is ſhaken over in it till it has acquired the ſhade which is wanted. In other whites, a blue tinge is given by adding a little blue to the ſolution of ſoap. The azure-white is communicated by means of indigo. To prepare the azure, fine indigo is well waſhed two or three times in moderately warm water, ground fine in a mortar, and boiling water poured upon it. It is then left to ſettle, and the liquid part only, which contains the finer and more ſoluble parts, is employed.

114. Some uſe no ſoap in the third operation; but when the ſecond is completed, they waſh the ſilks, fumigate with ſulphur, and azure them with river water, which ſhould be very pure. But all theſe operations are not ſufficient to give ſilk that degree of brightneſs which is neceſſary, when it is to be employed in the manufacture of white ſtuffs. For this purpoſe it muſt undergo the proceſs of ſulphuration, in which the ſilk is expoſed to the vapour of ſulphur, for an account of which ſee **Bleaching**. But before the ſilk which has been treated in this way is fit for receiving colours, and retaining them in their full luſtre, the ſulphur which adheres to it muſt be ſeparated by immerſion and agitation for ſome time in warm water, otherwiſe the colours are tarniſhed and greatly injured.

Mode of extracting its colouring matter.

115. It has long been an object of conſiderable importance, to deprive ſilk of its colouring matter, without deſtroying the gum, on which its ſtiffneſs and elaſticity depend. A proceſs for this purpoſe was diſcovered by Beaumé, but as it was not made public, others have been led to it by conjecture and experiment. The following account, given by Berthollet, is all that has tranſpired concerning this proceſs. A mixture is made with a ſmall quantity of muriatic acid and alcohol. The muriatic acid ſhould be in a ſtate of purity, and particularly ſhould be entirely free from nitric acid, which would give the ſilk a yellow colour. In the mixture thus prepared, the ſilk is to be immerſed. One of the moſt difficult parts of the proceſs, eſpecially when large quantities are operated upon, is to produce a uniform whiteneſs. In dyeing the whitened ſilk, there is alſo conſiderable difficulty, to prevent its curling, ſo that it is recommended to keep it conſtantly ſtretched during the drying. The muriatic acid ſeems to be uſeful in this proceſs, by ſoftening the gum, and aſſiſting the alcohol to diſſolve the colouring particles which are combined with it. The alcohol which has been impregnated with the colouring matter may be again ſeparated from it and purified, that it may ſerve for future operations, and thus render the proceſs more economical. This may be done by means of diſtillation with a moderate heat, in glaſs or ſtone-ware veſſels.

Aluming.

116. The preparation with alum is a very important preliminary operation in the dyeing of ſilk. Without this proceſs, few colours would have either beauty or durability. Forty or fifty pounds of alum, previouſly diſſolved in warm water, are mixed in a vat, with forty or fifty pailfuls of water; and to prevent the cryſtallization of the ſalt, the ſolution muſt be carefully ſtirred during the mixture. The ſilk being previouſly waſhed and beetled, to ſeparate any remains of ſoap, is immerſed in this alum liquor, and at the end of eight or nine hours is wrung out, and waſhed in a ſtream of water. A hundred and fifty pounds of ſilk may be prepared in the above quantity of liquor; but when it begins to grow weak, which may be known by the taſte, 20 or 25 lbs. of diſſolved alum are to be added, and the addition repeated till the liquor acquires a diſagreeable ſmell. It may then be employed in the preparation of ſilk intended for darker colours, till its whole ſtrength is diſſipated. This preparation of ſilk with alum muſt be made in the cold; for when the liquor is employed hot, the luſtre is apt to be impaired.

Sect. III. *Of Cotton.*

Origin.

117. Cotton is the down or wool contained in the pods of a ſhrubby plant, which is a native of warm climates. Of this genus of plants (*Goſſypium* Lin.) there are four ſpecies, one of which only is perennial; the other three are annual plants; but of theſe there are many varieties, occaſioned by the difference of ſoil or temperature in which they are produced. The principal differences among cottons conſiſt in the length and fineneſs of the filaments, and in their ſtrength and colour.

Structure.

118. The peculiar ſtructure of the fibres of cotton is not well known. According to the microſcopic obſervations of Leeuwenhoek, they have two ſharp ſides, to which are aſcribed the irritation and inflammation of wounds and ulcers, when they are dreſſed with cotton inſtead of lint. This peculiarity of ſtructure, it is alſo ſuppoſed, may occaſion ſome difference in the conformation, and number of the pores, on which alone the diſpoſition of cotton to admit and retain colours better than linen, ſeems to depend. In this reſpect, however, it is inferior to wool and ſilk, becauſe on account of its vegetable nature, its affinity for colouring matter is leſs powerful.

Has a leſs affinity than wool for colouring matter.

119. It is well known that ſilk, cotton, and linen have a weaker affinity for colouring matter than wool. Le Pileur d'Apligny attempts to explain this by ſuppoſing that

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that the pores of theſe ſubſtances are ſmaller than thoſe of wool, and that the colouring particles enter them leſs eaſily and freely. But according to the obſervation of Dr Bancroft, the reverſe of this ſeems to be the fact; for there is little difficulty in making ſilk, cotton, and linen, imbibe colouring matter, even when it is applied cold without any artificial dilatation of the pores, which is always neceſſary in the dyeing of wool. The only real difficulty is to make them retain the colours after the matter has been imbibed; becauſe being admitted ſo readily into their undilated pores, the particles cannot be afterwards compreſſed and retained by the contraction of theſe pores, as is the caſe with wool. It requires double the quantity of cochineal which is neceſſary for wool to communicate a crimſon colour to ſilk; a certain proof that it can take up a greater quantity, and conſequently that the pores are ſufficiently large and acceſſible. Unbleached cotton is always preferred for dyeing Turkey red; becauſe in this ſtate the colour is found to be moſt permanent; and this is aſcribed to the pores or interſtices being leſs open than after it has undergone the proceſs of bleaching. The ſame thing is obſerved of raw or unſcoured ſilk. It is found to combine more eaſily with the colouring matter, and to receive a more permanent colour in this ſtate than after it has been ſcoured and whitened. "The openneſs of cotton and linen, (ſays Dr Bancroft) and their conſequent readineſs to imbibe, both colouring particles, and the earthy or metallic baſes employed to fix moſt of them, are circumſtances upon which the art of dyeing and callico-printing is in a great degree founded *." But is not this too mechanical an explanation of the phenomenon? Might it not rather be alleged that it is owing to a difference of affinities which exiſts between the particles of colouring matter and the ſubſtance which is ſeparated from the ſilk or cotton by the proceſſes of bleaching or ſcouring. This ſubſtance probably acts the part of a mordant; and having a ſtronger affinity for the ſtuff and for the colouring matter than the ſtuff has for the latter, the colour communicated is more durable when ſilk or cotton is dyed in the unbleached or unſcoured ſtate.

Preparations for dyeing.

120. To prepare cotton ſtuffs for receiving the dye, ſeveral operations are neceſſary. It muſt firſt undergo the proceſs of ſcouring. By ſome it is boiled in ſour water, or in alkaline ley. It ſhould be kept boiling for two hours, then wrung out, and rinſed in a ſtream of water till the water comes off clear. The ſtuffs to be prepared ſhould be ſoaked for ſome time in water, mixed with not more than $\frac{1}{50}$ part of ſulphuric acid, and then carefully waſhed in a ſtream of water, and dried. In this operation the acid combines with a portion of calcareous earth and iron, which would have interrupted the full effect of the colouring matter in the proceſs of dyeing.

Aluming.

121. Aluming is another preliminary proceſs in the dyeing of cotton. The alum is to be diſſolved in the manner already deſcribed, in preparing ſilk. Each pound of cotton ſtuff requires four ounces of alum. By ſome a ſolution of ſoda, about $\frac{1}{16}$th part of the alum, and by others, a ſmall quantity of tartar and arſenic are added. The thread is to be impregnated by working it in ſmall quantities with this ſolution. The whole is then put into a veſſel, and the remaining part of the liquor is poured upon it. In this ſtate it is left for 24 hours, after which it is removed to a ſtream of water, and allowed to remain for an hour and a half, or two hours, to extract part of the alum. It is then to be waſhed. By this operation, cotton is found to gain an addition of about $\frac{1}{40}$th part of its weight.

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Galling.

122. The operation of galling is another preparatory proceſs in the dyeing of cotton ſtuffs. The quantity of aſtringent matter employed muſt be proportioned to its quality, and the amount of the effect required. Powdered galls are boiled for two hours in a proportion of water, regulated by the quantity of thread to be galled. This ſolution being reduced to ſuch a temperature as the hand can bear, is divided into a number of equal parts, that the thread may be wrought pound by pound. The whole ſtuff is then put into a veſſel, and the remaining liquor poured upon it, as in the former proceſs. It is then left for 24 hours, if it is to be dyed black, but for other colours, 12 or 15 hours are found ſufficient. It is then wrung out and dried.

In the galling of cotton ſtuffs, which have already received a colour, the precaution ſhould be obſerved of performing this operation in the cold, otherwiſe the colour is ſubject to injury.

123. Berthollet informs us, that cotton which has been alumed acquired more weight in the galling than that which had not previouſly undergone that proceſs; for although alum adheres but in ſmall quantities to cotton, it communicates to it a greater power of combining, both with the aſtringent principle, and with the colouring particles. This, we may add, may be conſidered as a good inſtance of the action of intermediate affinities, and of the advantage to be derived to the art of dyeing, from inveſtigating and obſerving this action.

Sect. IV. *Of Flax.*

Origin.

124. Flax and hemp nearly reſemble each other in their general properties; and ſo far as relates to the proceſſes of dyeing, what is ſaid of the one may be applied to the other. Flax or lint is obtained from the bark of *Linum uſitatiſſimum*, and hemp from that of *Cannabis ſativa.*

Watering.

125. Before flax is properly prepared to receive the dye, it muſt be ſubjected to ſeveral proceſſes. One of the moſt important is that of watering, by which the fibrous parts of the plant are ſeparated, and brought to that ſtate in which they can be ſpun into threads. As the quantity and quality of the product depend much on this preliminary operation, it becomes of the greateſt conſequence that it be properly conducted. During this proceſs, carbonic acid and hydrogen gas are given out. The extrication of theſe gaſes is owing to a glutinous juice which holds the green colouring part of the plant in ſolution, and which is the medium of union between its cortical and ligneous parts, undergoing a certain degree of putrefaction. This ſubſtance ſeems to reſemble the glutinous part which is held diſſolved in the juice obtained from plants by preſſure; is ſeparated from the colouring particles by means of heat; readily becomes putrid, and by diſtillation affords ammonia. But although it is held in ſolution with the expreſſed juice, it would appear that it cannot be ſeparated from the cortical parts completely, by means of water; and hence it happens, that hemp or flax watered

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* *Philoſ. of Permanent Colours*, 71.

watered in too ſtrong a current, has not the requiſite ſoftneſs and flexibility. But on the other hand, if the water employed in this operation be ſtagnant and in a putrid ſtate, the hemp or flax becomes of a brown colour, and loſes its firmneſs. In the one caſe, the putrefactive proceſs is interrupted; in the other it is continued too long, and carried too far. This proceſs, therefore, is performed with the greateſt advantage in places near the banks of rivers, where the water may be changed ſo frequently as to prevent ſuch a degree of putrefaction as would be injurious to the flax, as well as prejudicial to the workmen, from noxious exhalations; and, at the ſame time, not ſo frequently as to retard or interrupt thoſe changes which are neceſſary for rendering the glutinous ſubſtance ſoluble in water.

126. By the proceſs of watering flax, and by drying before and after that proceſs, the green coloured particles undergo a ſimilar change to that which is obſerved in the green ſubſtance of the plants expoſed to the action of air and light. The next part of the proceſs, therefore, after watering, is to ſpread it out upon the graſs, and thus expoſe it for ſome time to the air and ſun. By this means the colour of the lint is improved, and the ligneous part becomes ſo brittle, that it is eaſily ſeparated from the fibrous part. This operation, as is well known, is uſually performed by machinery.

Structure.

127. The fibres of lint poſſeſs no perceptible degree of elaſticity, and they appear to be perfectly ſmooth. No roughneſs or inequality can be detected by the feel, and no aſperities can be perceived, even with the aſſiſtance of the microſcope. Experience ſhows, that it produces no irritation on wounds or ſores which are dreſſed with it, as is known to happen from a ſimilar application of cotton ſtuffs.

Preparation for dyeing.

128. Flax which is intended for dyeing muſt be ſubjected to a ſimilar ſeries of operations with cotton in the different proceſſes of ſcouring, aluming and galling. A repetition of the mode of performing theſe operations is therefore unneceſſary.

Chap. IV. *Of the Operations of Dyeing.*

129. Before we proceed to the detail of the proceſſes of dyeing, we ſhall throw out a few hints on the operations in general, ſome of which may perhaps be uſeful to the practical dyer.

Advantages of large manufactories.

130. The works which are carried on in extenſive manufactories, it has been obſerved, are followed with advantages which are unknown to thoſe which are conducted on a limited ſcale or in a detached manner. By the ſubdiviſion of labour each workman directing his attention to one or a few objects, acquires a great facility and perfection of execution, by which means the ſaving of time and labour becomes conſiderable. This principle is particularly applicable to the art of dyeing, becauſe the preparation which remains after one operation may often be advantageouſly employed in another. A bath from which the colouring matter has been in a great meaſure extracted in the firſt operation, may be uſeful as a ground for other ſtuffs, or with the addition of a freſh portion of ingredients may form a new bath. The galls which have been applied to the galling of ſilk may anſwer a ſimilar purpoſe for cotton or wool. From this it muſt appear that the limitations and reſtrictions under which the art of dyeing labours in ſome countries muſt tend to obſtruct its progreſs and improvement. An extenſive plan of operations, by which the different branches of the art are connected together, would effectually prevent the loſs of ingredients, time, fuel, and labour.

Dye-houſes.

131. A dye-houſe, which ſhould be ſet down as near as poſſible to a ſtream of water, ſhould be ſpacious and well lighted. It ſhould be floored with lime and plaſter; and proper means ſhould be adopted to carry off water or ſpent baths by forming channels or gutters, ſo that every operation may be conducted with the utmoſt attention to cleanlineſs.

Caldrons.

132. The ſize and poſition of the caldrons are to be regulated by the nature and extent of the operations for which they are deſigned. Excepting for ſcarlet and other delicate colours, in which the tin is uſed as a mordant, in which caſe tin veſſels are preferable, the caldrons ſhould be of braſs or copper. Braſs, being leſs apt than copper to be acted on by means of chemical agents, and to communicate ſpots to the ſtuffs, is fitter for the purpoſe of a dyeing veſſel. It is ſcarcely neceſſary to ſay that it is of the greateſt conſequence that the coppers or caldrons be well cleaned for every operation; and that veſſels of a large ſize ſhould be furniſhed at the bottom with a pipe and ſtop-cock for the greater conveniency of emptying them: and there muſt be a hole in the wall or chimney above each copper to admit poles for the purpoſe of draining the ſtuffs which are immerſed, ſo that the liquor may fall back into the veſſel, and no part may be loſt.

Apparatus for ſilk.

133. Dyes for ſilk where a boiling heat is not found neceſſary, are prepared in troughs or backs, which are long copper or wooden veſſels. The colours which are uſed for ſilk are extremely delicate. They muſt therefore be dried quickly, that they may not be long expoſed to the action of the air, and there may be no riſk of change. For this purpoſe, it is neceſſary to have a drying room heated with a ſtove. The ſilk is ſtretched on a moveable pole, which by the dyers is called a ſhaker. This is hung up in the heated chamber, and kept in conſtant motion to promote the evaporation.

For ſtuffs of cloth.

134. For pieces of ſtuffs, a winch or reel muſt be conſtructed; the ends of which are ſupported by two iron forks which may be put up at pleaſure in holes made in the curb on which the edges of the copper reſt. The manipulations in dyeing are neither difficult nor complicated. Their object is to impregnate the ſtuff to be dyed with the colouring particles, which are diſſolved in the bath. For this purpoſe, the action of the air is neceſſary, not only in fixing the colouring particles, but alſo in rendering them more vivid; while thoſe which have not been fixed in the ſtuff are to be carefully removed. In dyeing whole pieces of ſtuff, or a number of pieces at once, the winch or reel mentioned above, muſt be employed. One end of the ſtuff is firſt laid acroſs it, and by turning it quickly round, the whole paſſes ſucceſſively over it. By turning it afterwards the contrary way, that part of the ſtuff which was firſt immerſed, will be the laſt in the ſecond immerſion, and thus the colouring matter will be communicated as equally as poſſible.

For wool.

135. In dyeing wool in the fleece, a kind of broad

ladder

ladder with very cloſe rounds, called by the dyers of this country, a *ſcraw*, or *ſcray*, is uſed. This is placed over the copper, and the wool is put upon it, for the purpoſe of draining and expoſure to the air, or when the bath is to be changed. If wool is dyed in the ſtate of thread, or in ſkains, rods are to be paſſed through them, and the hanks turned upon the ſkain ſticks in the liquor. This is called *ſhaking over*. When ſilk or thread is in the ſame ſtate, it undergoes a ſimilar operation.

Wringing out.

136. To ſeparate the ſuperabundant colouring particles, or thoſe which have not been fixed in the ſtuff, ſilk or thread, after being dyed, it muſt be wrung out. This operation is performed with a cylindrical piece of wood, one end of which is fixed in the wall, or in a poſt. This operation is often repeated a number of times ſucceſſively, for the purpoſe of drying the ſtuffs more rapidly, and communicating a brighter luſtre.

Raking.

137. When, after a certain quantity of freſh ingredients is added to a liquor, and it is ſtirred about, it is ſaid to be *raked*, becauſe it is mixed with the rake.

Giving a ground.

138. In dyeing, one colour is frequently communicated to ſtuffs, with the intention of applying another upon it, and thus a compound colour is produced. The firſt of theſe operations is called *giving a ground*.

Dipping.

139. When it is found neceſſary to paſs ſtuffs ſeveral times through the ſame liquor, each particular operation is called a *dip*.

Terms for different ſhades.

140. A colour is ſaid to be *roſed*, when a red colour having a yellow tinge, is changed to a ſhade inclining to a crimſon or ruby colour; and the converſion of a yellow red to a more complete red, is called *heightening* the colour.

141. In addition to theſe general remarks, we might give more minute details of the different operations which are employed in dyeing; but as we cannot preſume that they would be of much advantage to the practical dyer, we ſhall not indulge ourſelves in uſeleſs deſcription. "Although the manipulations of dyeing," ſays Berthollet, are not very various, and appear extremely ſimple, they require very particular attention, and an experienced eye, in order to judge of the qualities of the bath, to produce and ſuſtain the degree of heat ſuited to each operation; to avoid all circumſtances that might occaſion inequalities of colour, to judge accurately whether the ſhade of what comes out of the bath ſuits the pattern, and to eſtabliſh the proper gradations in a ſeries of ſhades"*.

Water important.

142. We ſhall conclude this chapter with a few obſervations on the qualities and effects of different kinds of water, which may be conſidered as one of the moſt eſſential agents in the art of dyeing. It is almoſt unneceſſary to ſay, that water which is muddy, or contains putrid ſubſtances, ſhould not be employed; and indeed no kind of water which poſſeſſes qualities diſtinguiſhed by the taſte, ought to be uſed. Water which holds in ſolution earthy ſalts, has a very conſiderable action on colouring matters, and it is chiefly by means of theſe ſalts. Such, for inſtance, are the nitrates of lime and magneſia, muriate of lime and magneſia, ſulphate of lime, and carbonate of lime and of magneſia.

143. Theſe ſalts which have earthy baſes, oppoſe the ſolution of the colouring particles, and by entering into combination with many of them, cauſe a precipitation, by which means the colour is at one time deeper, and at other times duller and more faint than would otherwiſe be the caſe. Water impregnated with the carbonates of lime and magneſia, yield a precipitate when they are boiled; for the exceſs of carbonic acid which held them in ſolution is driven off by the heat; the earths are thus precipitated, and adhering to the ſtuffs to be dyed, render them dirty, and prevent the colouring matter from combining with them.

144. It is of much conſequence to be able to diſtinguiſh the different kinds of water which come under the denomination of *hard water*, that they may be avoided in the eſſential operations of dyeing; but to detect different principles contained in ſuch waters, and to aſcertain their quantity with preciſion, require great ſkill, and very delicate management of chemical operations, which the experienced chemiſt only can be ſuppoſed to poſſeſs. For the methods to be followed when ſuch accuracy is required, we muſt refer to the analyſis of mineral waters, of which a full view is given in the treatiſe on chemiſtry, and content ourſelves with mentioning ſome ſimple teſts which are of eaſy application.

145. One of theſe teſts is the ſolution of ſoap, by which it may be diſcovered whether water contains ſo large a portion of any of theſe ſaline matters as may be injurious to the proceſſes. Salts which have earthy baſes, have the property of decompoſing ſoap by the action of double affinity. The acid of the ſalt combines with the alkali of the ſoap, and remains in ſolution, while the earth of the ſalt and the oil of the ſoap enter into combination, and form an earthy ſoap which is inſoluble in water, and produces the curdling appearance which is the conſequence of this new combination. Water, then, which is limpid and not ſtagnant, which has no perceptible taſte or ſmell, and has the property of diſſolving ſoap without decompoſition, may be conſidered as ſufficiently pure for the proceſſes of dyeing. All waters which poſſeſs theſe qualities will be found equally proper for theſe purpoſes.

Method of purifying.

146. But, as it is not always in the power of the dyer to chooſe pure water, means of correcting the water which would be injurious to his proceſſes, and particularly for the dyeing of delicate colours, have been propoſed. Water in which bran has been allowed to become ſour, is moſt commonly employed for this purpoſe. This is known by the name of *ſours*, or ſour water. The method of preparing ſour water is the following. Twenty four buſhels of bran are put into a veſſel that will contain about 10 hogſheads. A large boiler is filled with water, and when it is juſt ready to boil, it is poured into the veſſel. Soon after the acid fermentation commences, and in about 24 hours the liquor is fit to be applied to uſe. Water which is impregnated with earthy ſalts, after being treated in this way, forms no precipitate by boiling. It is probable that the ſour water decompoſes the carbonate of lime and magneſia, becauſe the vegetable acid which is formed during the fermentation, combines with the earthy baſis, and ſets the carbonic acid at liberty.

147. Some of the ſubſtances with which waters are impregnated, or thoſe which are merely diffuſed in them in a ſtate of very minute diviſion, may be ſeparated by means of mucilaginous matters. The mucilage

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* *Elem. of Dyeing.* i. 162.

coagulates by means of heat, and carrying with it the earths ſeparated by boiling, as well as thoſe ſubſtances which are ſimply mixed with the water, and render it turbid, riſes to the ſurface, and forming a ſcum, may be eaſily removed.

148. Saline matters having earthy baſes, which in general are injurious in dyeing, may in ſome caſes be uſeful, becauſe by their action, modifications of different colours may be produced. A water of this kind, for inſtance, would have the effect of communicating to the colour of cochineal a crimſon ſhade.

149. River water, which is apt to be impregnated with earthy ſalts, may, at different times contain very different proportions of theſe ſalts; and although the dyer may follow exactly the ſame proceſs, he may be ſurpriſed to find conſiderable variations in the ſhades of his colours. This ariſes from the different degrees of impregnation with theſe ſaline matters which the water undergoes, as the bed of the river is of greater or leſs extent, or the waters flow over thoſe places from which they derive theſe earthy ſalts. To obtain the ſame reſult in the proceſs, therefore, it would be neceſſary to make certain variations according to the ſtate of impregnation of the water.

PART II. OF THE PRACTICE OF DYEING.

150. IN the preceding part, we have endeavoured to give a general view of the principles on which the art of dyeing depends. We have conſidered the phyſical and chemical properties of colours and colouring matters; the nature of the ſubſtances to which colours are communicated, and the agents or means by which this is effected; and from the experiments and obſervations of philoſophers, whoſe inveſtigations have been directed to this ſubject, it appears that theſe changes are entirely owing to chemical affinities, by which decompoſitions are effected, and new combinations formed, among the conſtituent parts of the ſubſtances employed. A preciſe and full knowledge of the effects of theſe chemical agents would render the theory of dyeing complete; and although much has been already done by the chemical philoſophers whom we have had occaſion frequently to quote, yet experiments and obſervations are ſtill wanting to form a theory of this art on fixed and rational principles. This, it is obvious, can only be done by chemical inveſtigations. To the practical dyer, therefore, the ſtudy of chemical ſcience muſt be eſſentially requiſite, as this only can be his true guide in eſtimating and managing the complicated changes in the different proceſſes of his art. It is only by the application of the principles of chemiſtry that this art can be improved and perfected. But the application of theſe principles muſt be made by the practical dyer himſelf, not by the chemiſt in his laboratory, or during an occaſional viſit to the manufactory. For in the complicated proceſſes of dyeing conducted on an extenſive ſcale, a thouſand circumſtances will be overlooked by the moſt acute and diſcerning chemiſt, which will not eſcape the habitual obſervation of the philoſophical artiſt. Convinced ourſelves of the incalculable advantages which the art of dyeing may derive from chemical ſcience, and the innumerable reſources which ingenuity and addreſs may diſcover in the proper application of its principles towards the improvement of the different proceſſes of this art, we ſhall not be thought, we hope, too ſanguine in looking forward to a degree of perfection which is little to be expected from its preſent ſtate.

Importance of chemiſtry in dyeing.

The proceſſes of the art of dyeing form the ſubject of the ſecond part of this treatiſe, the conſideration of which we are now to enter upon.

Diviſion of colours.

151. Colours have been uſually diſtributed by dyers into two claſſes. Theſe have been denominated *ſimple* and *compound* colours. Simple colours, which are commonly reckoned four in number, are ſuch as cannot be produced by the mixing together different colours. Colours denominated compound may be produced by the mixture of any two of the ſimple colours in different proportions. Thus red, yellow, and blue are incapable of being produced by any combination of others, and are therefore conſidered as ſimple colours. Blue and red, which compoſe a purple, blue and yellow, a green, and red and yellow, an orange, are compound colours; but none of theſe, by any compoſition whatever, will afford a red, yellow, or blue.

Dr Bancroft's.

152. Dr Bancroft in his elaborate treatiſe on the philoſophy of permanent colours, divides colouring matters into two claſſes. The firſt includes thoſe colouring ſubſtances which, being in a ſtate of ſolution, may be permanently fixed on any ſtuff without any mordant, or the intermediate action of earthy or metallic baſes. In the ſecond claſs are comprehended thoſe matters which cannot be fixed without the action of mordants. The firſt he has denominated *ſubſtantive* colours; becauſe the colour is fixed without the aid of any other body: and the ſecond *adjective;* becauſe they become permanent only with the addition of a mordant. The celebrated purple produced by the liquor obtained from ſhell-fiſh and indigo, are examples of ſubſtantive colours. Pruſſian blue and cochineal are adjective colours.

The uſual diviſion of colours into ſimple and compound ſeems to form an arrangement equally convenient and perſpicuous. We ſhall therefore adopt it in the following chapters. In the firſt we ſhall treat of *ſimple* colours; in the ſecond of *compound* colours; and to theſe we ſhall add a third chapter on topical dyeing, or calico printing.

CHAP. I. *Of Simple Colours.*

Simple colours.

153. SIMPLE colours, we have already obſerved, are ſuch as cannot be produced by the mixture of other colours. They are the foundation of all other colours, and therefore come naturally to be firſt treated of. The ſimple colours are four, viz. 1. Red. 2. Yellow. 3. Blue. 4. Black. To theſe a fifth is added by ſome; namely, brown, or fawn colour; although it may be produced by the combination of other colours. The nature of the colouring ſubſtances which are employed

to

to produce theſe colours, and the proceſſes by which they are fixed on the ſeveral ſtuffs, will form the ſubjects of the four following ſections.

Sect. I. *Of Red.*

154. Red colours, from different degrees of intenſity, have received different names, as crimſon, ſcarlet, beſides a great variety of ſhades which are leſs ſtriking, and come under no particular denomination. In this ſection we ſhall treat of the nature and properties of the ſubſtances which are employed in dyeing red, and then give an account of the different proceſſes which are followed in fixing theſe colouring matters on animal and vegetable productions.

1. *Of the Subſtances employed in Dyeing Red.*

The colouring matters which are principally employed in dyeing red, are *madder*, *cochineal*, *kermes*, *lac*, *archil*, *carthamus*, *braſil wood*, and *logwood*.

Madder.

155. Madder is very extenſively employed in dyeing. It is the root of a plant (*rubia tinctorum*, Lin.) of which there are two varieties. It is cultivated in different parts of Europe, and the beſt, it is ſaid, is brought from Zealand. Madder, as it is prepared for dyeing, is diſtinguiſhed into different kinds. What is called *grape madder*, is obtained from the principal roots; the *none grape* is produced from the ſtalks, which by being buried in the earth, are converted into roots, and are called layers. When the roots are gathered, theſe layers are ſeparated, with ſuch of the fibres of the roots as do not exceed a certain degree of thickneſs, as well as thoſe which are too thick; the latter containing a great deal of woody matter. The beſt roots are about the thickneſs of a gooſe quill, they have ſome degree of tranſparency; are of a reddiſh colour, and have a ſtrong ſmell, and a ſmooth bark. When the madder is gathered, it muſt be dried, to render it fit for being reduced to powder, and being preſerved. This operation is performed in warm climates in the open air. In Holland, ſtoves are employed for the ſame purpoſe; but when treated in this way, it is often injured, from too great a degree of heat, and being mixed with particles of ſoot. The ſuperiority of madder from the Levant is aſcribed to its having been dried in the open air.

Preparation.

156. The roots being dried, and the earthy matters which adhere to them being ſeparated, by ſhaking them in a bag, or beating them lightly on a wooden hurdle, they are reduced to powder, by means of manual labour, or with the aid of machinery. All the parts of madder do not yield the ſame colouring matter. The outer bark, and the ligneous part within, give a yellowiſh dye, which injures the red. Theſe parts may be ſeparated in conſequence of the different degrees of facility with which they are reduced to powder. The outer bark and woody parts are more eaſily powdered than the parenchymatous parts, which contain the fine red dye. To effect the ſeparation of theſe different parts, three operations are performed. After the firſt, the madder is paſſed through a ſieve, by which, what is called the *ſhort* madder, (*courte* of the French), intended for tan, and inferior colours, is obtained. What remains is again ground and ſifted. What the French call *mirobèe*, is obtained by this operation. A third operation of the ſame kind affords the *robèe*, or finer kind of madder.

157. The reſult of the experiments of D'Ambourney ſhew, that the freſh root of madder may be uſed with as much advantage in dyeing, as when it is dried and powdered. Four pounds of freſh madder, he obſerved, are equal to one of the dry, although in drying it loſes ſeven-eighths of its weight. When the freſh roots are to be uſed, they are to be well waſhed in a current of water, immediately after they are taken out of the ground, and afterwards cut into pieces and bruiſed. In dyeing with the freſh roots, allowance ſhould be made for the quantity of water which they contain, ſo that a ſmaller proportion ſhould be put into the bath. Beckmann ſeems to be of the ſame opinion with regard to the uſe of the freſh roots of madder, and yet he has frequently obſerved that it is more fit for dyeing after it has been preſerved for two or three years.

158. The madder which is cultivated in the neighbourhood of Smyrna, and in the iſland of Cyprus, affords a brighter red than the European madder, and therefore it is preferred in the preparation of the *Adrianople red*. This is known by the name *lizari*. Berthollet informs us that it is cultivated in Provence in France, and Beckmann has been very ſucceſsful in raiſing it at Gottingen.

Properties.

159. The colouring matter of madder is ſoluble in alcohol, and by evaporation a deep-red reſiduum is formed. In this ſolution ſulphuric acid produces a fawn-coloured precipitate; fixed alkali, one of a violet colour, and the ſulphate of potaſh, a precipitate of a fine red. Alum, nitre, chalk, acetate of lead, and muriate of tin, afford precipitates in the ſolution of madder in alcohol, of various ſhades. The colouring matter of madder is alſo ſoluble in water. By maceration in ſeveral portions of cold water ſucceſſively, the laſt receives only a fawn colour, which appears entirely different from the peculiar colouring particles of this ſubſtance. It reſembles what is extracted from woods and other roots, and perhaps exiſts only in the ligneous and cortical parts. By repeated boiling, Berthollet exhauſted the madder of all its colouring particles which are ſoluble in water. It ſtill retained, however, a deep colour, and yielded a conſiderable quantity of colouring matter to an alkali. There was an inconſiderable reſiduum, which ſtill remained coloured. The pulp, therefore, appears entirely compoſed of colouring matter, part of which is inſoluble in ſimple water. When oxymuriatic acid is employed in ſufficient quantity, to change an infuſion of madder from red to yellow, it produces a ſmall portion of a pale-yellow precipitate; the ſupernatant liquor is tranſparent, and retains more or leſs of a deep yellow colour, according to the proportion and ſtrength of the acid. Double the quantity of acid is required to diſcharge the colour of a decoction of madder of what is neceſſary to deſtroy that of the ſame weight of Brazil wood. This ſhews that the colouring matter of madder is more durable than that of Brazil wood. The infuſion of madder in water is of a browniſh orange colour. The colouring matter may be extracted, either by hot or cold water; in the latter the colour is moſt beautiful. The decoction is of a browniſh colour. The colouring matter of mad-

der

der cannot be extracted without a great deal of water. Two ounces of madder require three quarts of water. Alum forms, in the infuſion of madder, a deep browniſh red precipitate; the ſupernatant liquor is yellowiſh, inclining to brown. Alkaline carbonates precipitate from this laſt liquor a lake of a blood-red colour; with the addition of more alkali, the precipitate is rediſſolved, and the liquor becomes red. Calcareous earth precipitates a darker and browner coloured lake than alkalies. Carbonate of magneſia forms a clear blood-red precipitate, which by evaporation produces a blood-red extract, ſoluble in water. The ſolution of this extract is employed as a red ink, but it becomes yellow by expoſure to the ſun. Metallic ſalts alſo form precipitates in a ſolution of madder. The precipitate with acetate of lead is of a browniſh red colour; with nitrate of mercury and ſulphate of manganeſe, a purpliſh brown; with ſulphate of iron, a fine bright brown.

Cochineal.

Hiſtory.

160. Cochineal, which furniſhes a valuable dye ſtuff, and about the nature of which there was at firſt a good deal of uncertainty, is an inſect. It is produced on different ſpecies of the *cactus*, or Indian fig. The moſt perfect variety of the cochineal inſect is that which breeds on the *cactus coccinillifer*, Lin. To this plant the Mexican Spaniards give the name of *nopal*. When the Spaniards firſt arrived in Mexico, they ſaw the cochineal employed by the native inhabitants, in communicating colours to ſome part of their habitations, ornaments, and in dyeing cotton. Struck with its beautiful colour, they tranſmitted accounts of it to the Spaniſh miniſtry, who about the year 1523, ordered Cortes to direct his attention to the propagation of this ſubſtance. The inhabitants of Europe were long miſtaken concerning the nature and origin of cochineal, by ſuppoſing it to be the grain or ſeed of a plant. This opinion was firſt contradicted in a paper publiſhed in the third volume of the Philoſophical Tranſactions, in 1668, and four years afterwards, Dr Liſter, in the ſeventh volume of the ſame work, throws out a conjecture, that cochineal may be a ſort of kermes. Different opinions concerning the origin of this ſubſtance were entertained, till about the beginning of the year 1757, Mr Ellis obtained ſome of the joints of the plant on which the inſects breed, from South Carolina, and preſented them the ſame year to the Royal Society. Theſe ſpecimens, Mr Ellis obſerves, were full of the neſts of this inſect, in which it appeared in its various ſtates, in the moſt minute when it walks about, to the ſtate when it becomes fixed, and wrapt up in a fine web, which it ſpins about itſelf. With the aſſiſtance of the microſcope, Mr Ellis diſcovered the true male inſect in the parcels which had been ſent to him from America; and in Auguſt 1759, in conſequence of Mr Ellis's diſcovery, Dr Garden caught a male cochineal fly, which he obſerves is rarely to be met with. He ſuppoſes that there may be 150 or 200 females for one male. Theſe diſcoveries proved indiſputably, that the cochineal is an animal production *.

* Philoſ. Tranſ. vol. lii.

161. The body of the female inſect is flat on the belly, and hemiſpherical on the back, and tranſverſely wrinkled. The ſkin is dark brown; it has no wings, but is furniſhed with ſix ſhort brown legs. The body of the male, which is of a deep red colour, is rather long, and covered with two wings, extending horizontally, and croſſing a little upon the back. It has two ſmall antennæ, and ſix legs, which are larger than thoſe of the female. It has a fluttering kind of motion. The life of the male is only of a month duration, but the fecundated female lives a month longer. The female is ſometimes oviparous and ſometimes viviparous; but this is not a peculiarity confined to this inſect. It belongs to ſome others, and ſeems to be regulated by the temperature and ſeaſon of the year. The female cochineal inſect adheres to the ſame ſpot of the tree on which it is produced during her whole life. As ſoon as the female is delivered of its numerous progeny, it becomes a mere huſk and dies. In Mexico it is therefore an object of great importance to prevent this, and to collect them in the fecundated ſtate. For this purpoſe they are picked from the plants, put into a linen bag, which is immerſed in hot water, to deſtroy the life of the young inſects, and then carefully dried. In this ſtate they are imported into Europe.

Varieties.

162. There are two kinds of cochineal. The beſt, or domeſticated kind, is called by the Spaniards, *grana fina*. This variety breeds upon the *cactus coccinillifer*, or nopal; and being of a larger ſize, and containing a greater proportion of colouring matter, it is always preferred. The other variety is the *grana ſylveſtra* of the Spaniards, or wild cochineal. It is produced from other ſpecies of the *cactus*. It is ſmaller than the other, and as it is covered with a downy matter, produced by the inſect to defend itſelf againſt the cold, this increaſes the weight, but is of no uſe in dyeing. An equal weight of the wild cochineal yields a ſmaller quantity of colouring matter, and is therefore leſs valuable. It ought, however, to be obſerved, that it can be reared with greater facility, and at much leſs expence; and when it is bred upon the nopal, it acquires double the ſize, and has a ſmaller quantity of downy matter for its covering, ſo that it approaches, by this management, to the nature of fine cochineal.

163. As the quantity of cochineal conſumed in Europe is very great (D), and as the Spaniards have hitherto enjoyed the excluſive advantages of rearing and ſupplying the market with this valuable ſubſtance, it has become an object with other nations to ſhare them. Attempts have therefore been made to form eſtabliſhments for rearing theſe inſects in thoſe colonies whoſe ſoil and climate ſeem ſuitable for the purpoſe.

(D) The average quantity, ſays Dr Bancroft, of fine cochineal annually conſumed in Europe, amounts to about 3000 bags, or 600,000 lbs. weight, of which about 1200 bags, or 240,000 lbs. weight may be conſidered as the preſent annual conſumption of Great Britain. A greater quantity comes into the kingdom, but the ſurplus is again exported to other countries. Theſe 1200 bags may be ſuppoſed to coſt 180,000l. ſterling, valued at 15s. per lb. which has been about the average price for ſome years paſt. *Philoſophy of Permanent Colours*, p. 258.

Attempts to cultivate it.

164. One of the moſt ſucceſsful of theſe attempts was made by M. Thiery de Menonville, in 1777. He expoſed himſelf to great danger, by going to Mexico, that he might obſerve the mode of rearing the cochineal inſect, and procure that valuable production, to plant it in St Domingo. He proceeded by the Havannah to La Vera Cruz, where he was informed that the fineſt cochineal inſects were reared at Guaxaca, 70 leagues diſtant. On the pretence of ill health, he received permiſſion to uſe the baths of the river Magdalene: but inſtead of accepting this privilege, which was not his object, he directed his courſe, not without much difficulty and danger, to Guaxaca; where having obtained the information he wanted, and having purchaſed a quantity of nopals, covered with the inſects of the fine or domeſtic breed, which he pretended were of great uſe in preparing an ointment for his feigned diſorder, the gout, he put them into boxes along with other plants, and ſucceeded in bringing them away without notice or ſuſpicion. On his return, he was driven by a ſtorm into the bay of Campeachy, where he found a living cactus of a ſpecies which was fit for the nouriſhment of the fine cochineal. He returned in ſafety towards the end of the ſame year, to St Domingo, with his prize, and immediately formed a plantation of nopals, with the view of propagating both varieties of the cochineal. Soon after his return, he found the wild kind living naturally on the *cactus pereſkia*, a native of that iſland. Unfortunately, however, for the eſtabliſhment, Thiery de Menonville died in the year 1780, through diſappointment and vexation, it is ſaid, at ſeeing his patriotic endeavours ſo little aſſiſted, and his ſervices ſo ſparingly rewarded by government; and ſoon after his death, the fine cochineal periſhed. But the diſcovery of the wild kind in St Domingo was not neglected. M. Bruley ſucceeded in his attempts to rear this ſpecies of cochineal. A poſthumous work of Thiery de Menonville was publiſhed by the Royal Society of arts and ſciences at Cape François, containing minute inſtructions with regard to every thing reſpecting the cultivation of the nopal, and the other ſpecies of cactus, which may be more or leſs ſucceſsfully ſubſtituted for breeding or rearing the cochineal. Of this Berthollet has given an extract in the 5th volume of the Annales de Chimie. Some of our own countrymen, a few years ago, ſucceeded in procuring ſome of the fine cochineal inſects; and attempts have been made, with what ſucceſs we know not, to rear them in the Eaſt Indies.

Properties.

165. Fine cochineal, if it has been properly prepared and kept, ought to be of a gray colour, with a ſhade of purple. The gray colour is owing to a powder with which it is naturally covered, and part of which it ſtill retains. The colouring matter extracted by the water in which the inſect has been killed, produces the purple ſhade. In a dry place, cochineal may be kept for a long time, without loſing any of its properties. Hellot made experiments on cochineal 130 years old, and found that it produced the ſame effect as if it had been quite new. Cochineal yields its colouring matter to water; and the decoction, which is of a crimſon colour, inclining to violet, may be kept for a long time, without loſing its tranſparency, or becoming putrid. If this decoction be evaporated, and the reſiduum or extract be digeſted in alcohol, the colouring part diſſolves, and leaves a reſiduum of the colour of wine lees, of which freſh alcohol cannot deprive it. The alcohol of cochineal affords, by evaporation, a tranſparent reſiduum of a deep red, which being dried, has the appearance of a reſin. A ſmall quantity of ſulphuric acid added to the decoction of cochineal, produces a red colour, inclining to yellow, and a ſmall quantity of a beautiful red precipitate. With muriatic acid the ſame change is produced, but there is no precipitate. A ſolution of tartar converts the decoction to a yellowiſh red colour. A precipitate of a pale red colour is ſlowly formed, and the ſupernatant liquor remains yellow; but with the addition of an alkali becomes purple. With the yellow liquor, ſolution of tin forms a roſe-coloured precipitate; ſolution of alum brightens the colour of the infuſion, gives it a redder hue, and produces a crimſon precipitate. With a mixture of alum and tartar the colour is brighter, more lively, and inclines to a yellowiſh red. Muriate of tin occaſions a copious ſediment of a beautiful red. The ſupernatant liquor is colourleſs and tranſparent, and no change is produced on it by adding an alkali. Sulphate of iron forms a brown violet precipitate, and the ſupernatant liquor remains clear, with a ſlight darkiſh hue. Sulphate of zinc gives a deep violet precipitate; the ſupernatant liquor remains colourleſs and tranſparent. The precipitate with ſulphate of copper is of a violet colour, and forms ſlowly: the ſupernatant liquor is alſo violet and tranſparent. Acetate of lead gives a purple violet precipitate, and the ſupernatant liquor remains limpid.

166. The experiments of Berthollet and Bancroft ſhew, that the colouring matter of cochineal is not entirely extracted by means of water. Dr Bancroft found, that after the whole of it which could be extracted by water was obtained, by adding a little potaſh to the ſeemingly exhauſted ſediment, and pouring on it freſh boiling water, it yielded a new quantity of colouring matter, equal to one-eighth of what had been given out to the water; and Berthollet found the ſame effect produced with the addition of tartar; from which he concludes, that tartar favours the ſolution of the colouring part of the cochineal.

Kermes.

167. Kermes (G), another animal ſubſtance, which is extenſively employed in dyeing, is an inſect, (*coccus ilicis*, Lin.) which breeds on a ſpecies of oak, (*quercus coccifera*, Lin.) which grows in moſt of the ſouthern parts of Europe, and in many parts of Aſia.

Hiſtory.

Kermes was known to the ancients, under the names of *coccum ſcarlatinum*, *coccus bapticus*, *coccus infectorius*, *granum tinctorium*. Kermes is chiefly obtained from Languedoc, Spain, and Portugal. The inſects are collected in the month of May or June, when the female, which

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(G) This word is ſuppoſed to have been derived from the Arabic language, and ſignifies a *little worm, vermiculus*; and from this we have the word *vermilion*, the pigment in the manufacture of which it is the principal ingredient.

alone is uſeful, is diſtended with eggs. To deſtroy the young inſects, the kermes is expoſed to the ſteam of vinegar for about half an hour, or ſteeped in vinegar for 10 or 12 hours. They are afterwards dried on linen cloths, and brought to market.

Properties.

168. When the living inſect is bruiſed, it gives out a red colour. The ſmell is ſomewhat pleaſant; the taſte is bitter and pungent. It gives out its colouring matter both to water and alcohol, to which alſo it imparts its ſmell and taſte. The colour is alſo retained in the extract which is obtained, both from the tincture, and from the infuſion. Kermes is one of the moſt ancient dyeing drugs; and although the colours which it communicates to cloth are leſs bright and vivid than thoſe of cochineal, and on that account it has been leſs extenſively employed in dyeing ſince the latter was known, yet they have been found to be exceedingly permanent. The fine blood-red colour which is to be ſeen on old tapeſtries in different parts of Europe, was produced from kermes, with an aluminous mordant, and ſeems to have ſuffered no change, though ſome of them are 200 or 300 years old. The colour obtained from kermes was formerly called ſcarlet in grain, becauſe it was ſuppoſed that the inſect was a grain; and from the chief manufactory having been at one time in Venice, it was called *Venetian ſcarlet*.

Lac.

169. *Lac* is an animal production which has been long known in India, and uſed for dyeing ſilk and other purpoſes. It is the *nidus* of the *coccus lacca*, Lin. and is generally produced on the ſmall branches of the *croton lacciferum*. Three kinds of lac are well known in commerce: 1. Stick lac is the ſubſtance or comb, in its natural ſtate, forming a cruſt on the ſmall branches or twigs. 2. Seed lac is ſaid to be only the above, ſeparated from the twigs, and reduced into ſmall fragments. History. Mr Hatchett, who has examined this ſubſtance with his uſual ſkill and preciſion, found the beſt ſpecimens conſiderably deprived of their colouring matter *. According to the information which he received from Mr Wilkins, the ſilk dyers in Bengal produce the ſeed lac by pounding crude lac into ſmall fragments, and extracting part of the colouring matter by boiling. 3. Shell lac is prepared from the cells, liquified, ſtrained, and formed into thin tranſparent laminæ. There is alſo a fourth kind called *lump lac*, which is obtained from the ſeed lac by liquefaction, and afterwards formed into cakes. The beſt lac is of a deep red colour; when it is pale, and pierced at the top, the value is greatly diminiſhed, for then the inſects have left their cells, and it can no longer be of uſe as a dye ſtuff.

Properties.

170. The decoction of powdered ſtick lac in water, gives a deep crimſon colour. With one-fifth of borax, lac becomes more ſoluble in water. Pure ſoda, and carbonate of ſoda, completely diſſolve the different kinds of lac, and produce a deeper colour than that which is obtained by means of borax. Pure potaſh ſpeedily diſſolves all the varieties of lac; the colour approaches to purple. Pure ammonia and carbonate of ammonia readily act on the colouring matter of lac. Alcohol diſſolves a conſiderable portion of the lac; and, according to Geoffroy, yields a fine red colour. When the ſolution is heated it becomes turbid. Sulphuric acid diſſolves the colouring matter of lac, as well as muriatic and acetic acids. In the uſe of lac in dyeing, it has been conſidered ſuperior to kermes, becauſe it is able to bear the action of a ſolution of tin, without the colour being changed to yellow.

Archil.

171. Archil is a vegetable ſubſtance of great uſe in dyeing. It is employed in the form of a paſte, which is of a red violet colour. It is chiefly obtained from two ſpecies of *lichen*, *roccella* and *parellus*, Lin. The firſt, which is called *Canary archil*, becauſe the lichen from which it is prepared grows abundantly in the Canary iſlands, is moſt valued. It is prepared by reducing the plant to a fine powder, which is afterwards paſſed through a ſieve, and ſlightly moiſtened with ſtale urine. The mixture is daily ſtirred, each time adding a certain proportion of ſoda in powder, till it acquire a clove colour. It is then put into a wooden caſk, and urine, lime-water, or a ſolution of ſulphate of lime, (*gypſum*,) is added in ſufficient quantity to cover the mixture. In this ſtate it is kept; but to preſerve it any length of time, it is neceſſary to moiſten it occaſionally with urine. By a ſimilar preparation, other ſpecies of lichen may be uſed in dyeing. In this country the *lichen omphalodes* and *tartareus* are frequently employed for dyeing coarſe cloths.

Properties.

172. Archil gives out its colouring matter to water, ammonia, and alcohol. The infuſion of archil is of a crimſon colour, with a ſhade of violet. The addition of an acid converts it to a red colour. Fixed alkalies only render it of a deeper ſhade; becauſe its natural colour has been already modified by the ammonia with which it is combined in the preparation. Alum produces in the ſolution of archil a dark-red precipitate; the ſupernatant liquor is of a yellowiſh red colour. With ſolution of tin a reddiſh precipitate is formed, which ſubſides ſlowly; and the liquor retains a ſlight tinge of red. This infuſion loſes its colour in a few days if it be entirely excluded from the air. To cold marble the aqueous infuſion of archil communicates a fine violet colour, or blue inclining to purple. The affinity between the ſtone and the colouring matter is ſo ſtrong, that it reſiſts the action of the air longer than colours which it gives to other ſubſtances. The colour thus communicated to marble, has remained for two years unchanged.

Singular change.

173. Archil is alſo ſoluble in alcohol. This tincture is employed for making ſpirit of wine thermometers. A ſingular phenomenon was obſerved by the Abbé Nollet when the tincture was excluded from the air. In a few years it was entirely deprived of its colour. The contact of air reſtored the colour; but it was again deſtroyed when deprived of it.

Carthamus.

174. Carthamus, or baſtard ſaffron, a vegetable ſubſtance uſed in dyeing, is the flower of an annual plant which is cultivated in Spain, Egypt, and the Levant. There are two varieties of this plant, the one with larger, the other with ſmaller leaves. The variety with larger leaves is cultivated in Egypt.

Preparation.

175. The method of preparing the flowers of carthamus in Egypt, as it is deſcribed by Haſſelquiſt, is the following. After being preſſed between two ſtones, to ſqueeze out the juice, they are waſhed ſeveral times with ſalt water, preſſed between the hands, and ſpread out on mats in the open air, to dry. In the day time they are covered, that they may not dry too faſt with the heat of the ſun, but they are left expoſed to the dew of the night. When they are ſufficiently dry, they are put

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* *Phil. Tranſ.* 1804.

put up, and kept for ſale, under the name of *ſaffranon*. Care ſhould be taken afterwards, not to keep it in too dry a place; for unleſs it is a little moiſt, its properties are conſiderably impaired.

Properties.

176. Carthamus contains two colouring ſubſtances, a yellow ſubſtance, which is ſoluble in water, and as it is of no uſe, it is extracted by the proceſs mentioned above, by ſqueezing the flowers between ſtones till no more colour can be preſſed out. The flowers become reddiſh in this operation, and loſe nearly one half of their weight. The other colouring matter, which is red, is ſoluble in alkaline carbonates, and it is precipitated by means of an acid. A vegetable acid, as lemon juice, has been found to produce the fineſt colour. Next to this, ſulphuric acid produces the beſt effect, provided too great a quantity, which would alter and deſtroy the colour, be not employed. The juice of the berries of the mountain aſh, or *rowan tree*, (*ſorbus aucuparia*, Lin.) is recommended by Scheffer as a ſubſtitute for lemon juice, and it is thus prepared. The berries are bruiſed in a mortar with a wooden peſtle, and the expreſſed juice, after it has been allowed to ferment, is bottled up. The clear part, which is moſt acid, becomes fitter for uſe the longer it is kept; but this operation requires a period of ſome months, and can only be conducted in ſummer.

Preparation of *rouge*.

177. From the colouring matter extracted by means of an alkali, and precipitated with an acid, is procured the ſubſtance called *rouge*, which is employed as a paint for the ſkin. The ſolution of carthamus is prepared with cryſtals of ſoda, and precipitated with lemon juice which has ſtood ſome days to ſettle. After being dried on delft plates with a gentle heat, the precipitate is ſeparated, and ground accurately with talc which has been previouſly reduced to a very ſubtile powder; and on the fineneſs of the talc depends the difference between the cheaper and dearer kinds of *rouge*.

Brazil wood.

178. Brazil wood is of very extenſive uſe in dyeing. It is the wood of the *cæſalpinia criſta*, Lin. and is a native of America and the Weſt Indies. It is known under different names, according to the place where it is produced; as, *Fernambouc*, *Braziletto*, *wood of St Martha*, and of *Sapan*. It is a very hard wood, and has ſo much denſity as to ſink in water. When freſh cut, it is of a pale colour, but becomes reddiſh by expoſure to the air, and it has a ſweetiſh taſte.

Properties.

179. The colouring matter of Brazil wood is ſoluble in water, and the whole of it may be extracted by continuing the boiling for a ſufficient length of time. The decoction is of a fine red colour. The reſiduum, which is black, yields a conſiderable portion of colouring matter to alkalies. This colouring matter is alſo ſoluble in alcohol, and in ammonia, and the colour is deeper than that of the aqueous ſolution. The tincture of Brazil wood in alcohol gives to hot marble a red colour, which afterwards changes to violet. The freſh decoction yields, with ſulphuric acid, a ſmall portion of a red precipitate, inclining to fawn colour. Nitric acid firſt produces a yellow colour, but by adding more, a deep orange. Oxalic acid produces a precipitate of an orange red. Tartar furniſhes a ſmall precipitate: with the addition of fixed alkali, the decoction becomes of a deep crimſon or violet colour. Ammonia gives a brighter purple; alum produces a copious red precipitate, inclining to crimſon. Sulphate of iron occaſions a black colour in the tincture, with a copious precipitate of the ſame colour. Sulphate of copper alſo produces an abundant precipitate, the liquor remaining tranſparent, and of a browniſh red. A copious precipitate of a fine deep red, is produced with acetate of lead, and that obtained with muriate of tin is abundant, and of a fine roſe colour. With the addition of corroſive ſublimate, a light precipitate, which is of a brown colour, is obtained. The liquor remains tranſparent, and of a fine yellow colour. Brazil wood which has been changed to a yellow colour by means of tartar and acetous acid, with a ſolution of nitro-muriate of tin, yields a copious roſe-coloured precipitate; and if to the ſolution, rendered yellow by an acid, a greater quantity of the ſame acid, or a ſtronger acid, as the ſulphuric, be added, the red colour is reſtored. Some ſalts alſo poſſeſs the property of reſtoring the red colour of Brazil wood, which has been deſtroyed by means of acids *. The decoction of Brazil wood, which is called juice of Brazil, is found to anſwer better for the proceſſes of dyeing, when it has been kept ſome time, and has even undergone ſome degree of fermentation, than when it has been freſh prepared. The colour, by keeping, becomes of a yellowiſh red.

Logwood.

Properties.

180. Logwood, ſometimes called India or Campeachy wood, (*Hæmatoxylon Campeachianum*, Lin.) is a tree which grows to a conſiderable ſize in Jamaica, and the eaſtern ſhore of the bay of Campeachy. Its ſpecific gravity is greater than that of water; it has a fine grain, and is ſuſceptible of a fine poliſh. Logwood yields its colouring matter, which is a fine red, readily and copiouſly to alcohol. It is more ſparingly ſoluble in water, and the decoction inclines a little to violet or purple. When it is left ſome time to itſelf, it becomes yellowiſh, and at length black. It becomes yellow alſo by the action of acids; alkalies produce a deeper colour, and convert it to a purple or violet. Sulphuric, nitric, and muriatic acids form a ſmall proportion of precipitate, which ſeparates ſlowly: the precipitate formed with ſulphuric acid is of a dark red; with muriatic, a lighter red, and with the nitric, *feuille mort*. With ſulphuric and muriatic acids, the ſupernatant liquor is of a deep red colour; with nitric it is yellowiſh, and in all tranſparent. Oxalic acid produces a precipitate of a light marone colour; the liquor remains tranſparent, and is yellowiſh red. Acetic acid produces a ſimilar effect, but the colour of the precipitate is ſomewhat deeper. A ſimilar precipitate is obtained by means of tartar; but the liquor, which is more inclined to yellow, remains turbid. No precipitate is produced by means of fixed alkali; the decoction becomes of a deep violet, which is afterwards converted to a brown colour. Alum yields a copious precipitate, of a lightiſh violet colour; the colour of the liquor remains the ſame, and it is nearly tranſparent. A copious, dark red precipitate is produced with alum and tartar; the liquor is yellowiſh red and tranſparent. Sulphate of iron occaſions a bluiſh black colour; a copious precipitate of the ſame colour is formed, and the liquor remains long turbid. With ſulphate of copper, a very copious precipitate, of a deep brown colour, is obtained; the liquor, which is alſo of a deep brown, or yellowiſh red, remains tranſparent. Acetate of lead yields a black precipitate,

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* *Jour. de Phyſ.* 1785.

with a ſlight tinge of red; the colour of the liquor is like that of pale beer, and it remains tranſparent. Nitro-muriate of tin gives a precipitate of a fine violet or purple colour; the liquor remains clear and colourleſs.

2. *Of the Proceſſes for Dyeing Wool Red.*

181. All red colouring matters with which we are acquainted, come under that claſs of colours to which Dr Bancroft has given the name of *adjective* colours; that is, ſuch colours as require the aid of mordants to render them permanent. Red colours, we have already obſerved, are of various ſhades, according to the nature and proportion of the colouring matters employed. Hence we have madder red, ſcarlet, crimſon, and other ſhades.

Madder red.

182. *Madder Red.*—Madder is only employed for dyeing coarſe woollen ſtuffs, and the following is the proceſs. The ſtuffs are firſt boiled for two or three hours with alum and tartar; they are then left to drain, ſlightly wrung out, put into a linen bag, and carried into a cool place, where they are to remain for ſome days. The quantities and proportions of the alum and tartar are varied according to the views of the dyer, and the ſhade of colour which is wanted. Some recommend five ounces of alum and one ounce of tartar to each pound of wool. By increaſing the proportion of tartar to a certain degree, a deep and permanent cinnamon colour, inſtead of a red, is produced. This ariſes from the yellow tinge which is induced by means of the acid on the colouring particles of the madder. Others propoſe to diminiſh the proportion of tartar, and to employ only a ſeventh part. In conducting the proceſs of dyeing with madder, the bath ſhould not be brought to the boiling point, becauſe at that temperature the fawn-coloured particles would be diſſolved, and a different ſhade obtained from that which is deſired. When the water is at that degree of temperature which the hand can bear, Hellot recommends the addition of half a pound of grape madder for every pound of wool to be dyed. It is then to be well ſtirred before the wool is introduced, which muſt remain for an hour without boiling, excepting for a few minutes towards the end of the proceſs, that the combination of the colouring particles with the ſtuff may be more certain.

Proceſs.

Roſing.

183. Madder reds are ſometimes roſed, as it is called, with archil and Brazil wood. In this way they become more beautiful and velvety, but this brightneſs is not permanent. But madder reds, even when they are moſt perfect, are far inferior to thoſe obtained from lac and cochineal, and even to that produced by kermes; but as the expence of the materials is comparatively ſmall, they are employed, as we have already obſerved, for coarſe ſtuffs.

Proportion of madder.

184. Different authors recommend different proportions of madder. Poerner propoſes to employ one-third of the weight of the wool, while Scheffer limits the quantity to one-fourth. In one proceſs, Poerner added to the alum and tartar, a quantity of ſolution of tin, equal in weight to the tartar, and after two hours boiling, allowed the cloth to remain in the bath, which had been left to cool for three or four days. He then dyed it in the uſual way, and thus obtained a fine red. According to another proceſs, he prepared the cloth by the common boiling, and dyed it in a bath ſlightly heated, with a larger proportion of madder, tartar, and ſolution of tin. The cloth remained 24 hours in the bath, and when it had become cold, he put it into another bath, made with madder only, where it remained for 24 hours. By this proceſs he got a fine red, ſomewhat brighter than the common, but inclining a little to yellow. Scheffer informs us that he obtained an orange red by boiling wool with a ſolution of tin, and one-fourth of alum, and then by dyeing with one-fourth of madder. A cherry colour is obtained, according to Bergman, by dyeing with one part of a ſolution of tin, and two of madder, without previouſly boiling the wool. By expoſure to the air, this colour becomes deeper. By boiling the wool for two hours with one-fourth of ſulphate of iron, then waſhing it, and afterwards immerſing it in cold water with one-fourth of madder, and then boiling for an hour, the reſult is a coffee colour. But if the wool has not been ſoaked, and if it be dyed with one part of ſulphate of iron and two of madder, the colour is a brown approaching to red.

Different mordants.

185. When ſulphate of copper is employed as the mordant, the madder dye yields a clear brown, inclining ſomewhat to yellow; and a ſimilar colour may be produced by dyeing the wool ſimply ſoaked in hot water, with one part of ſulphate of copper, and two of madder. But when this mordant and dye-ſtuff are uſed in equal proportions, the yellow is ſomewhat more obſcure, approaching to green; and in both theſe inſtances, expoſure to the air does not produce a darker colour. Berthollet informs us that he employed a ſolution of tin in various ways, both in the preparation and in the application of the madder; and by the uſe of different ſolutions of tin, he found, that although the tint was ſomewhat brighter than what is obtained by the common proceſs, it was always more inclined to yellow or fawn colour.

Scarlet.

186. *Scarlet.*—The fineſt and moſt ſplendid of all colours is ſcarlet. This, like other colours, is of various ſhades, according to the quality and proportion of the colouring matter employed. The ſcarlet dye is communicated to woollen ſtuffs by means of cochineal, the hiſtory and properties of which we have already detailed. The Mexicans, as appears from their hiſtory, employed alumina as the baſis or mordant, to fix the colour of cochineal; and previous to the diſcovery of the ſolution of tin, the uſe of the ſame ſubſtance ſeems to have prevailed in Europe. The fine colour obtained from the latter, received, as we have already mentioned, different names in different places; as that of *bow dye* in England, *ſcarlet of the Gobelins* in France, and in Holland *Dutch ſcarlet.*

Proceſs.

187. In the proceſs for dyeing ſcarlet, two operations are neceſſary. The firſt is denominated the boiling, and the ſecond is diſtinguiſhed by the name of finiſhing or reddening. The operation of boiling, which is the firſt part of the proceſs, is conducted in the following manner. For 100 pounds of cloth, 6 pounds of pure tartar are added to the water, which is made pretty warm. The bath is then to be briſkly ſtirred, and when the heat has increaſed a little more, half a pound of powdered cochineal is to be added, and the whole is then to be well mixed. The next moment five pounds of a very clear ſolution of tin are to be poured

Boiling.

Of Simple Colours.

poured in, and carefully mixed. When the bath begins to boil, the cloth is introduced, and briſkly moved for two or three turns; after which it is moved more ſlowly. The boiling having continued for two hours, the cloth is taken out, expoſed to the air, and carried to the river to be well waſhed.

Reddening.

188. In the preparation of the ſecond bath, which is for the reddening, the boiler is to be emptied, and when the bath has juſt reached the boiling point, five pounds and three quarters of cochineal, previouſly powdered and ſifted, are to be added. Theſe are to be carefully mixed; and after having ceaſed ſtirring, when a cruſt has formed on the ſurface, and opened of itſelf in ſeveral places, 13 or 14 pounds of ſolution of tin are poured in. Should the bath, during the boiling, riſe above the edge of the boiler, it may be cooled with a little cold water. This ſolution being well mixed, the cloth is put in, and two or three times quickly turned. It is then boiled in the bath for an hour, taking care to keep it under the ſurface. It is afterwards taken out, expoſed to the air, and when it has cooled, waſhed in the river and dried.

Proportion of ingredients.

189. There are no determinate proportions of cochineal and ſolution of tin in either of theſe operations. Hellot informs us, that ſome dyers employ two-thirds of ſolution of tin, and one-fourth of cochineal, in the boiling or firſt operation, and the other one-third of the ſolution of tin with the remaining three-fourths of the cochineal in the ſecond operation, or the reddening. He adds farther, that the uſe of tartar gives a greater degree of permanency to the colour, provided the proportion do not exceed one-half the weight of the cochineal employed. According to Berthollet, ſeveral dyers at preſent adopt this practice. Tartar, he obſerves, promotes the ſolution of the colouring matter, and this effect is greater when it is ground with the cochineal, after which it is found that the reſiduum is more completely exhauſted. But this conſideration is of inferior conſequence, when the operations are ſucceſſively performed, becauſe any colouring matter that may remain in the reſiduum, is employed in the next operation. It ought not, however, to be overlooked, that the tartar communicates to the colour a roſey hue.

Shorter proceſs.

190. It is the practice of ſome dyers not to remove the cloth out of the boiling. They merely refreſh it, and perform the operation of reddening in the ſame bath. When this is done, the infuſion of cochineal, made in a ſeparate veſſel, and mixed with the proper proportion of ſolution of tin, is added. By conducting the proceſs in this way the ſcarlet is ſuppoſed to be equally fine, and there is a conſiderable ſaving of time and fuel.

Brighter red.

191. To give ſcarlet the bright lively red which, as it approaches to the colour of fire, has been diſtinguiſhed by the name of *fiery ſcarlet*, a yellow tinge is communicated by boiling fuſtic in the firſt bath, or by adding a little turmeric to the cochineal. A larger proportion of the ſolution of tin alſo produces this yellow ſhade, but it renders the cloth harſh, and limits the action of the colouring matter. The uſe of fuſtic or turmeric, therefore, although the colour obtained from them is not permanent, is preferable to an exceſs of the ſolution of tin. When theſe ſubſtances are uſed, the inſide of the cloth, when it is cut, appears yellow; but in the ordinary proceſſes, the cochineal, it is found, does not penetrate the cloth, for when no other ſubſtance is employed, the cloth is internally white.

Of Simple Colours.

Tin and copper boilers.

192. The uſe of tin boilers is recommended in dyeing ſcarlet. When copper boilers are employed, the acid acts on the metal, and thus forming a ſolution, injures the beauty of the colour. Tin boilers, however, are attended with ſeveral inconveniences. It is difficult to procure them of ſufficient ſize, and they are apt to be melted by the incautious continuance of the fire, after they have been emptied. In the uſe of copper boilers, there are ſeveral neceſſary precautions. They muſt be kept very clean; the acid liquor ſhould not be allowed to remain in them for any length of time, and ſome contrivance ſhould be adopted to prevent the cloth from touching the metal, either by uſing a net, or a wicker baſket.

Different proportion of ingredients.

193. Different proportions of materials, we have obſerved, are recommended by different authors. For the boiling, Scheffer directs an ounce and a half of ſolution of tin, with an equal quantity of ſtarch, and as much tartar, to every pound of cloth. The effect of the ſtarch is to give more uniformity to the colour. When the water boils, a dram of cochineal is to be added; it is then to be well ſtirred, and after the wool is introduced, to be boiled an hour, taken out, and waſhed. The proportions for the reddening bath, in which the wool is to be boiled half an hour, are half an ounce of ſtarch, three-fourths of an ounce of ſolution of tin, half an ounce of tartar, and 7 drams of cochineal. In Scheffer's proceſs, it may be obſerved, the proportion of ſolution of tin is ſmaller than in that of Hellot, but the quantity of tin in the ſolution of the former is greater than in that of the latter.

Poerner's proceſs.

194. Poerner has deſcribed three principal proceſſes, according to the variety of the ſhade of the ſcarlet. He uſes no cochineal in the boiling; the materials of which are one ounce and ſix drams of tartar, and an equal weight of ſolution of tin, the latter being added after the tartar is diſſolved, for every pound of cloth. As ſoon as the boiling has commenced, the cloth is introduced, and it is boiled for two hours. For the reddening of the firſt proceſs he employs two drams of tartar and one ounce of cochineal, adding gradually afterwards two ounces of ſolution of tin. For the reddening of the ſecond proceſs, the ſame quantity of cochineal and ſolution of tin, without any tartar, is employed. In the reddening of the third proceſs, two drams of tartar, with one ounce of ſolution of tin, one ounce of cochineal, and two ounces of common ſalt, are directed to be uſed. The colour produced in the firſt proceſs has the deepeſt ſhade; that of the ſecond is more lively, while that of the third is paler and brighter.

Different ſhades.

195. By the uſe of tartar in the reddening in different proportions, various ſhades of ſcarlet may be obtained. When it is employed, the ſhade is deeper and fuller, but when it is entirely omitted, the ſcarlet approaches to an orange colour. The ſhade of colour alſo is ſubject to conſiderable variety, from the different degrees of ſtrength of the ſolution of tin. To aſcertain this effect, Berthollet made a number of experiments. He found that a ſolution of tin compoſed of ſixteen parts of nitric acid, two of muriate of ammonia,

monia, and three of tin, produced a deeper ſhade than when the proportions of the acid and muriate of ammonia were equal, with only two parts of tin. The laſt proportions, he obſerves, ſucceeded beſt. Four parts of water were mixed with the ſolution. When the proportion of muriate of ammonia amounted only to half a part, the colour was brighter, and inclining to orange.

Uſe of common ſalt.

196. Common ſalt has the effect of increaſing the brightneſs of ſcarlet, while it is alſo attended with the advantage of cauſing the colour to penetrate deeper into the cloth. It ſeems difficult to explain why common ſalt, which gives a deeper ſhade to the colour of the infuſion of cochineal, and indeed produces a ſimilar effect on colours in general, ſhould diminiſh the intenſity of the colour of ſcarlet. The proportion of common ſalt mentioned above (194) is, according to Poerner, the greateſt that can be employed. When leſs is uſed, the ſhade, though lighter, is more agreeable. By adding five ounces of white ſugar to the ingredients of the ſecond proceſs, a finer colour, which is always lighter than that of the firſt proceſs, will be obtained. The colour, it is ſaid, is more permanent, and the ſhade more agreeable, when the cloth is left 24 hours in the boiler after it has cooled.

Proceſs of dyeing ſcarlet with cochineal

197. It has been generally ſuppoſed, Dr Bancroft obſerves, that after the diſcovery of the effects of tin on the cochineal colour, to produce a ſcarlet, it was only neceſſary to apply the colour ſo produced as a dye to wool; or that a nitric or nitro-muriatic ſolution of tin might change the natural crimſon of cochineal to a ſcarlet. This opinion, however, he conſiders to be quite erroneous; for the nitric ſolution of tin invariably produces with cochineal a crimſon or roſe colour, and not a ſcarlet, unleſs other means are employed to incline the cochineal colour to a yellow ſhade. This effect is produced by means of the tartar, which ſeems to have been accidentally ſtumbled upon, and has been for many ages uſed, without knowing its true effect. Tartar was long employed with the aluminous mordant, in the preparation of the ordinary boiling liquor for woollen cloths; and it is probable that its good effects being obſerved in this combination, the uſe of it was continued after the introduction of the ſolution of tin; and the more ſo, after the reſult of the combination was obſerved in the brilliancy of the colour which was produced. Dr Bancroft has particularly directed his attention to the proceſs for dyeing ſcarlet; and in the progreſs of his inveſtigations, he has found that it is by no means abſolutely neceſſary to follow the uſual proceſs which we have deſcribed above. He has often, he ſays, produced that colour very well at a ſingle boiling, by mixing the whole quantity of tartar, ſolution of tin, and cochineal together; the affinity of the wool for the colouring matter, and for the oxide of tin, being ſufficiently ſtrong to combine with them readily, and to retain them permanently. The only objection to ſimplifying the proceſs in this manner is, that the colouring matter of the dyeing liquor is leſs perfectly exhauſted than when two operations are performed. He farther adds, that he has often produced a beautiful ſcarlet, by preparing and boiling the cloth with the whole quantity of ſolution of tin and tartar at once, and afterwards dyeing it unrinſed, with the whole of the cochineal, diſſolved only in pure water. In this way he found the colouring particles completely taken up; that the liquor had become quite colourleſs, and that the cloth had received a durable dye.

long ſtationary.

198 "It is remarkable," ſays Dr Bancroft, "that during the 18th century, no conſiderable improvement has been made in the proceſs for dyeing ſcarlet; a circumſtance which is the more extraordinary, ſince the pre-eminent luſtre and coſtly nature of this dye, have rendered it an object of particular attention, not only to dyers, but to eminent chemiſts, by whoſe reſearches we might have expected that at leaſt every obvious improvement therein would have been long ſince attained." To attain this object, this ingenious philoſopher inſtituted a ſet of experiments, about the year 1786.

Dr Bancroft's experiments.

Having, by repeated affuſions of boiling water, extracted the whole of the colouring matter from powdered cochineal, he found that the addition of a little potaſh to the ſeemingly exhauſted ſediment, and a freſh quantity of boiling water, extracted a new portion of colouring matter, equal to about one-eighth of what had been given out to the pure water. He repeatedly extracted this colouring matter by means of potaſh, and afterwards dyed ſmall pieces of cloth ſcarlet with it, which he found ſimilar to other pieces dyed with the more ſoluble colouring matter of cochineal. It was in the courſe of theſe inquiries that he perceived ſcarlet to be a compound colour, conſiſting of about three-fourths of pure crimſon or roſe colour, and one-fourth of pure bright yellow.

Scarlet a compound colour.

He conceived, therefore, that when the natural crimſon of the cochineal is made ſcarlet, by the uſual proceſs, there muſt be a change produced, equivalent to a converſion of one-fourth of the colouring matter of cochineal from its natural crimſon to a yellow colour. From this he concludes that there might be a great ſaving of cochineal, by ſubſtituting a cheaper ſubſtance, which at the ſame time might yield a better yellow colour. It was therefore his object to combine with this crimſon or roſe colour, a ſuitable portion of a lively golden yellow, capable of being permanently fixed, and reflected by the ſame baſis. Such a yellow he had diſcovered in quercitron bark, (*quercus nigra*, Lin.) which will be afterwards deſcribed; and it had the advantage, not only of being the brighteſt, but alſo the cheapeſt of all the yellows, which he had tried.

199. With the view of diminiſhing the quantity of cochineal employed, in producing a ſcarlet dye, Dr Bancroft made a number of experiments under the authority of government. In theſe experiments, the mordant uſed was the ordinary dyers ſpirit, or the nitro-muriate of tin; but he found that they were not attended with the advantages which he expected. In ſome of his earlieſt experiments, he obſerves, that the ſolution of tin by means of ſulphuric acid deſtroyed the cochineal colour; and this naturally led him to reject the uſe of this acid, till accident brought him to diſſolve a quantity of tin in muriatic acid, combined with one-fourth of ſulphuric acid. The application of this ſolution in dyeing, was not accompanied with the corroſive effects of the muriate and nitro-muriate which he had employed in the experiments above alluded to, and which proved unſucceſsful. After trying different proportions of theſe acids, he found the following to anſwer beſt. In a mixture of 2lbs. of ſulphuric acid of the ordinary ſtrength, and about 3lbs. of muriatic

acid, he diſſolved about 14 oz. of tin. The muriatic acid is firſt poured on a large quantity of granulated tin, in a large glaſs receiver, and the ſulphuric acid is then ſlowly added. The ſolution is more rapidly promoted by means of a ſand heat, but it will take place in the cold, requiring only a greater length of time. This murio-ſulphate of tin is tranſparent and colourleſs, and may be kept for ſeveral years without any precipitation. It produces twice the effect of the dyers ſpirit, at leſs than one-third of the expence, and raiſes the colours not only more than the dyers ſpirit, but alſo full as much as the tartrate of tin, without converting the crimſon of cochineal to a yellowiſh ſhade.

Dr Bancroft's proceſs.

200. In the uſe of this ſolution of tin as a mordant, to produce the compound ſcarlet colour with the cochineal crimſon and quercitron yellow, Dr Bancroft recommends the following proceſs. "Nothing," ſays he, "is neceſſary but to put the cloth, ſuppoſe 100lb. weight, into a proper tin veſſel, nearly filled with water, in which about eight pounds of the murio-ſulphuric ſolution of tin have been previouſly mixed, to make the liquor boil, turning the cloth as uſual through it, by the winch, for a quarter of an hour; then turning the cloth out of the liquor, to put into it about four pounds of cochineal, and two pounds and a half of quercitron bark in powder, and having mixed them well, to return the cloth again into the liquor, making it boil, and continue the operation as uſual until the colour be duly raiſed, and the dyeing liquor exhauſted, which will be the caſe in about fifteen or twenty minutes; after which the cloth may be taken out and rinſed as uſual. In this way the time, labour, and fuel, neceſſary for filling and heating the dyeing veſſel a ſecond time, will be ſaved; the operation finiſhed much more ſpeedily than in the common way; and there will be a ſaving of all the tartar, as well as of two-thirds of the coſt of ſpirit, or nitro-muriatic ſolution of tin, which for dyeing 100lb. of wool, commonly amounts to 10s; whereas, 8 lb. of the murio-ſulphuric ſolution will only coſt about 3s. There will be moreover a ſaving of at leaſt one-fourth of the cochineal uſually employed, (which is generally computed at the rate of one ounce for every pound of cloth,) and the colour produced will certainly not prove inferior in any reſpect to that dyed with much more expence and trouble in the ordinary way. When a roſe-colour is wanted, it may be readily and cheaply dyed in this way, only omitting the quercitron bark, inſtead of the complex method now practiſed of firſt producing a ſcarlet, and then changing it to a roſe by the volatile alkali contained in ſtale urine, ſet free or decompoſed by potaſh or by lime: and even if any one ſhould ſtill unwiſely chooſe to continue the practice of dyeing ſcarlet without quercitron bark, he need only employ the uſual proportions of tartar and cochineal, with a ſuitable quantity of the murio-ſulphate of tin, which, whilſt it coſts ſo much leſs, will be more effectual than the dyers ſpirit.

Saving of cochineal.

201. "Several hundreds of experiments warrant my aſſertion, that at leaſt a fourth part of the cochineal generally employed in dyeing ſcarlet, may be ſaved by obtaining ſo much yellow as is neceſſary to compoſe this colour from the quercitron bark; and indeed nothing can be more ſelf-evident, than that ſuch an effect, *cæteris paribus*, ought neceſſarily to reſult from this combination of different colouring matters, ſuited to produce the compound colour in queſtion. Let it be recollected that the cochineal crimſon, though capable of being changed by tartar towards the yellow hue on one hand, is alſo capable by other means of being changed towards a blue on the other, and of thereby producing a purple without indigo or any other blue colouring matter: yet I am confident that nobody would believe a pound of cochineal ſo employed capable alone of dyeing as much cloth, of any particular ſhade of purple, as might be dyed with it, if the whole of its colouring matter were employed ſolely in furniſhing the crimſon part of the purple, whilſt the other (blue) part thereof was obtained from indigo. To ſay that a pound of cochineal alone could produce as much effect or colour as a pound of cochineal and a pound of indigo together, would be an improbability much too obvious and palpable for human belief; and there certainly would be a ſimilar improbability in alleging, that a pound of cochineal, employed in giving another compound colour (ſcarlet), could alone produce as much effect as a pound of cochineal and a pound of quercitron bark, when the colour of this laſt was employed only in furniſhing one of the component parts of the ſcarlet, for which a conſiderable portion of the colouring matter of the cochineal muſt otherwiſe have been expended, which certainly happens in the new mode of dyeing ſcarlet, becauſe the colour produced with an addition of the quercitron yellow inclines no more towards a yellow, than the ſcarlet produced by yellowing a part of the cochineal colour in the uſual method with tartar. I retain, therefore, at this moment, as much confidence as I ever had in the reality and importance of my propoſed improvements in this reſpect (H.)

Advantages of this proceſs.

202. "The ſcarlet compoſed of cochineal crimſon and quercitron yellow, is moreover attended with this advantage, that it may be dyed upon wool and woollen yarn without any danger of its being changed to a roſe or crimſon, by the proceſs of fulling, as always happens to ſcarlet dyed by the uſual means. This laſt being in fact nothing but a crimſon or roſe colour, yellowed by ſome particular action or effect of the tartar, is liable to be made crimſon again by the application of

many

(H) "Of the benefit which I formerly expected to obtain by employing potaſh to extract a part of the cochineal colour, which water alone did not appear capable of extracting, it muſt be remarked that I have ſome time ſince convinced myſelf of its being an illuſion; for, by repeated trials, I have found that the ſolid parts of powdered cochineal remaining after it has been boiled with the ſolution of tin, as in the common dyeing proceſs, yield no colour worth notice, upon the application of potaſh, the ſolution of tin enabling the water to extract the colour ſufficiently; ſo that in truth there is no ſuch waſte of cochineal colour as I had ſuppoſed in the uſual way of employing that drug."

many chemical agents, (which readily overcome the changeable yellow produced by the tartar,) and particularly by calcareous earths, ſoap, alkaline ſalts, &c. But where the cochineal colouring matter is applied and fixed merely as a crimſon or roſe colour, and is rendered ſcarlet by ſuperadding a very permanent *quercitron yellow*, capable of reſiſting the ſtrongeſt acids and alkalies, (which it does when dyed with ſolutions of tin,) no ſuch change can take place, becauſe the cochineal colour having never ceaſed to be crimſon, cannot be rendered more ſo, and therefore cannot ſuffer by thoſe impreſſions or applications which frequently change or ſpot ſcarlet dyed according to the preſent practice."

Effect of candle light on this ſcarlet dye.

203. "There is alſo a ſingular property attending the compound ſcarlet dyed with cochineal and quercitron bark; which is, that if it be compared with another piece of ſcarlet dyed in the uſual way, and both appear by day-light exactly of the ſame ſhade, the former, if they be afterwards compared by candle-light, will appear to be at leaſt ſeveral ſhades higher and fuller than the latter; a circumſtance of ſome importance, when it is conſidered how much this and other gay colours are generally worn and exhibited by candle-light during a conſiderable part of the year."

Effects of murio-ſulphuric ſolution of tin.

204. "To illuſtrate more clearly the effects of the murio-ſulphuric ſolution of tin with cochineal in dyeing, I ſhall ſtate a very few of my numerous experiments therewith; obſerving, however, that they were all ſeveral times repeated, and always with ſimilar effects.

"1ſt, I boiled one hundred parts of woollen cloth in water, with eight parts of the murio-ſulphuric ſolution of tin, during the ſpace of ten or fifteen minutes; I then added to the ſame water four parts of cochineal, and two parts and a half of quercitron bark in powder, and boiled the cloth fifteen or twenty minutes longer; at the end of which it had nearly imbibed all the colour of the dyeing liquor, and received a very good, even, and bright ſcarlet. Similar cloth dyed of that colour at the ſame time in the uſual way, and with a fourth part more of cochineal, was found upon compariſon to have ſomewhat leſs body than the former; the effect of the quercitron bark in the firſt caſe having been more than equal to the additional portion of cochineal employed in the latter, and made yellow by the action of tartar."

"2d, To ſee whether the tartrite of tin would, beſides yellowing the cochineal crimſon, contribute to raiſe and exalt its colour more than the murio-ſulphate of that metal, I boiled one hundred parts of cloth with eight parts of the murio-ſulphuric ſolution, and ſix parts of tartar, for the ſpace of one hour; I then dyed the cloth, unrinſed, in clean water, with four parts of cochineal, and two parts and a half of quercitron bark, which produced a bright aurora colour, becauſe a double portion of yellow had been here produced, firſt by the quercitron bark, and then by the action of tartar upon the cochineal colouring matter. To bring back this aurora to the ſcarlet colour, by taking away or changing the yellow produced by the tartar, I divided the cloth whilſt unrinſed into three equal parts, and boiled one of them a few minutes in water ſlightly impregnated with potaſh; another in water with a little ammoniac; and the third in water containing a very little powdered chalk, by which all the pieces became ſcarlet; but the two laſt appeared ſomewhat brighter than the firſt, the ammoniac and chalk having each roſed the cochineal colour rather more advantageouſly than the potaſh. The beſt of theſe, however, by compariſon, did not ſeem preferable to the compound ſcarlet dyed without tartar, as in the preceding experiment; conſequently this did not ſeem to exalt the cochineal colour more than the murio-ſulphate of tin; had it done ſo, the uſe of it in this way would have been eaſy, without relinquiſhing the advantages of the quercitron yellow."

"3d, I boiled one hundred parts of woollen cloth with eight parts of the murio-ſulphuric ſolution of tin, for about ten minutes, when I added four parts of cochineal in powder, which by ten or fifteen minutes more of boiling, produced a fine crimſon. This I divided into two equal parts, one of which I yellowed or made ſcarlet by boiling it for fifteen minutes with a tenth of its weight of tartar in clean water; and the other, by boiling it with a fortieth of its weight of quercitron bark, and the ſame weight of murio-ſulphuric ſolution of tin; ſo that in this laſt caſe there was an addition of yellow colouring matter from the bark, whilſt in the former no ſuch addition took place, the yellow neceſſary for producing the ſcarlet having been wholly gained by a change and diminution of the cochineal crimſon; and the two pieces being compared with each other, that which had been rendered ſcarlet by an addition of quercitron yellow, was, as might have been expected, ſeveral ſhades fuller than the other."

"4th, I dyed one hundred parts of woollen cloth ſcarlet, by boiling it firſt in water with eight parts of murio-ſulphate of tin, and twelve parts of tartar, for ten minutes, and then adding five parts of cochineal, and continuing the boiling for fifteen minutes. This ſcarlet cloth I divided equally, and made one part crimſon, by boiling it with a little ammoniac in clean water; after which I again rendered it ſcarlet, by boiling it in clean water, with a fortieth of its weight of quercitron bark, and the ſame weight of murio-ſulphate of tin; and this laſt, being compared with the other half, to which no quercitron yellow had been applied, was found to poſſeſs much more colour, as might have been expected. A piece of the cloth, which had been dyed ſcarlet by cochineal and quercitron bark, as in the firſt experiment, being at the ſame time boiled in the ſame water with ammoniac, did not become crimſon, like that dyed ſcarlet without the bark.

205. "In this way of compounding a ſcarlet from cochineal and quercitron bark, the dyer will at all times be able, with the utmoſt certainty, to produce every poſſible ſhade between the crimſon and yellow colours, by only increaſing or diminiſhing the proportion of bark. It has indeed been uſual at times, when ſcarlets approaching nearly to the aurora colour were in faſhion, to ſuperadd a fugitive yellow either from turmeric, or from what is called young fuſtic (*Rhus Cotinus*); but this was only when the cochineal colour had been previouſly yellowed as much as poſſible by the uſe of tartar, as in the common way of dyeing ſcarlet; and therefore that practice ought not to be confounded

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confounded with my improvement, which has for its object to preclude the loſs of any part of the cochineal crimſon, by its converſion towards yellow colour, which may be ſo much more cheaply obtained than the quercitron bark. By ſufficient trials, I have ſatisfied myſelf that the cochineal colours, dyed with the murio-ſulphuric ſolution of tin, are in every reſpect at leaſt as durable as any which can be dyed with any other preparation of that metal; and they even ſeem to withſtand the action of boiling ſoap ſuds ſomewhat longer, and therefore I cannot avoid earneſtly recommending its uſe for dyeing roſe and other cochineal colours, as well as for compounding a ſcarlet with the quercitron bark."

206. Dr Bancroft afterwards tried a great variety of earthy and metallic ſalts, as mordants, for the purpoſe of fixing the colour of cochineal on wool; and he found that, beſides the metallic oxides and ſolutions, the aluminous, calcareous and ſiliceous earths, as well as magneſia and barytes, might be employed with different ſucceſs in dyeing with the colouring matter of cochineal: but for the detail of theſe experiments which he has given, we refer our readers to the treatiſe itſelf *.

Different ſhades of ſcarlet.

207. To produce different ſhades of ſcarlet, and the other colours which are derived from it, all that is neceſſary, is to vary the proportions of cochineal, tartar, and ſolution of tin; and for the ſhades which incline moſt to yellow, the addition of quercitron bark, or fuſtic, is requiſite. The uſe of the tartar is to deepen the colour, and the ſolution of tin produces a ſhade of orange. When the ſhade of colour required to be communicated to the ſtuff is light, the time of continuing the proceſs muſt be ſhortened †.

208. *Crimſon.*—The proceſſes which are employed to dye wool a crimſom colour, are two. The ſtuff is either dyed crimſon at once, or the crimſon ſhade is commnnicated to it, after being previouſly dyed of a ſcarlet colour.

Crimſon dyed by one proceſs,

To dye crimſon by a ſingle proceſs, a ſolution of two ounces and a half of alum, and an ounce and a half of tartar for every pound of ſtuff, is employed for the boiling, and the ſtuff is afterwards to be dyed with an ounce of cochineal. It is uſual alſo to employ ſolution of tin, but in ſmaller proportion than for dyeing ſcarlet. The proceſſes employed, it is ſcarcely neceſſary to obſerve, muſt vary, according as the ſhade wanted is deeper or lighter, or more or leſs diſtant from ſcarlet. Common ſalt is alſo employed by ſome in the boiling. To render the crimſon deeper, and to give it more bloom, archil and potaſh are frequently uſed; but this bloom, it ought to be obſerved, is extremely fugacious. By adding tartar and alum, the boiling for crimſon is ſometimes prepared after a ſcarlet reddening, and it is ſaid that the colour poſſeſſes more bloom, when both the boiling and reddening are made after ſcarlet, than when the crimſon is dyed in a freſh bath prepared on purpoſe. In dyeing theſe colours, the wild cochineal may be employed, but as it contains a ſmaller proportion of colouring matter, the quantity muſt be greater.

or by the converſion of ſcarlet.

209. Different ſubſtances, as the alkalies, alum, and earthy ſalts in general, convert the colour of ſcarlet to crimſon, which is the natural colour of cochineal. To effect this, the ſtuff previouſly dyed ſcarlet is boiled for an hour in a ſolution of alum, the ſtrength of which is to be regulated by the depth of ſhade required. In conducting this proceſs, it is neceſſary to obſerve, that water impregnated with earthy ſalts has a conſiderable effect in varying the ſhade; ſo that the quantity of alum employed muſt be proportioned to the purity of the water. Hellot tried ſoap, ſoda, potaſh, and ſome other ſubſtances, and although they produced the crimſon, yet it was of a deeper ſhade, and had leſs luſtre, than what was produced by means of alum. Ammonia produced a good effect; but from its great volatility, a conſiderable proportion muſt be put into the bath, moderately heated, with a little ſal ammoniac, and an equal quantity of potaſh. By this proceſs the ſtuff became of a bright roſy colour, and thus rendered a ſmaller quantity of cochineal neceſſary. Poerner directs the ſtuff previouſly dyed ſcarlet, to remain 24 hours in a cold ſolution of ſal ammoniac and potaſh.

Half-grain crimſon, &c.

210. To produce crimſons, as well as ſcarlets, in half grain, madder is to be ſubſtituted for half the quantity of the cochineal; or in other proportions, according to the ſhade deſired. The ſame boiling is given as for ſcarlet in grain, and the other parts of the proceſs are to be conducted as for reddening the ſcarlet or crimſon. Even the common madder red aſſumes a greater degree of luſtre, when the boiling is made after a reddening for ſcarlet ‡.

3. *Of the Proceſſes for dyeing Silk Red.*

Different proceſſes with madder.

211. *Madder red.*—The colour which is obtained from madder does not poſſeſs ſufficient brightneſs for dyeing ſilk. We ſhall here, however, deſcribe ſome of the proceſſes which are employed for this purpoſe. That of De la Folie, is the following. Half a pound of alum is to be diſſolved in each quart of hot water, and two ounces of potaſh are afterwards to be added. When the efferveſcence has ceaſed, and the liquor has become clear, the ſilk muſt be kept in it for two hours, after which it is to be waſhed, and put into the madder-bath. The ſilk which is dyed in this way becomes more beautiful by means of the ſoap proof. The proceſs of Scheffer is ſomewhat different. For each pound of ſcoured ſilk, he directs a ſolution of four ounces of alum, and ſix drams of chalk to be prepared. When the ſediment has formed, the ſolution is to be decanted, and having become quite cold, the ſilk is immerſed in it, and left for 18 hours. It is then taken out, and dried, and afterwards dyed with an equal weight of madder. The colour thus obtained is of a dark ſhade. Mr Guliche deſcribes another proceſs. For every pound of ſilk he propoſes a bath of four ounces of alum and one ounce of ſolution of tin. When the liquor has become clear, it is decanted, and the ſilk carefully ſoaked in it for 12 hours, after which it is to be immerſed in a bath with half a pound of madder ſoftened by boiling, with an infuſion of galls in white wine. The bath is to be kept moderately hot for an hour, and then made to boil for two minutes. The ſilk being taken from the bath, is to be waſhed in a ſtream of water, and dried in the ſun. The colour thus obtained is very permanent. By leaving out the galls it is clearer. The brightneſs of the firſt colour may be conſiderably increaſed, by paſſing the ſtuff through a bath of brazil-wood, to which one ounce of ſolution of tin is added.

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* *Phil. of Perm. Col.* 300.

† *Berthollet*, ii. 194.

‡ *Ibid.* ii. 198.

In this way the colour becomes extremely beautiful and durable.

Proceſs with Brazil wood.

212. Silk is ſometimes dyed with brazil wood, and the colour thus obtained has been diſtinguiſhed by the name of *falſe crimſon*, to diſtinguiſh it from the more durable colour which is produced by cochineal. The ſilk, after being boiled with ſoap, is to be alumed. It is then to be refreſhed at the river, and dipped in a bath more or leſs charged with brazil juice, according to the depth of ſhade required. If pure water be employed, the colour will be too red for crimſon; but to remedy this, the ſtuff may be paſſed through a weak alkaline ſolution, or a little alkali may be added to the bath, or the ſtuff may be waſhed in hard water till it has acquired the proper ſhade. To deepen the ſhade of falſe crimſons, or dark reds, the ſolution of logwood is added to the brazil bath, the ſilk being previouſly impregnated with the latter; or a little alkali may be added, according to the ſhade required.

With cochineal.

213. The crimſon produced by cochineal is called *grain crimſon*, to diſtinguiſh it from falſe crimſon. The ſilk, being well cleanſed from the ſoap at the river, is to be immerſed in an alum liquor of the full ſtrength, and to remain for a night. It is then to be waſhed, and twice beetled at the river. The bath is prepared by filling a long boiler two-thirds with water, to which are added, when it boils, from half an ounce to two ounces of powdered white galls for every pound of ſilk. When it has boiled for a few moments, from two to three ounces of cochineal alſo powdered and ſifted, for every pound of ſilk, are put in, and afterwards one ounce of tartar to every pound of cochineal. When the tartar is diſſolved, one ounce of ſolution of tin is added for every ounce of tartar. In the preparation of this ſolution of tin the following proportions are recommended by Macquer. For every pound of nitric acid two ounces of ſal ammoniac, ſix ounces of fine grain tin, and twelve ounces of water are employed. When theſe ingredients are mixed together, the boiler is to be filled up with cold water, and the proportion of the bath for every pound of ſilk is about eight or ten quarts of water. In this the ſilk is immediately immerſed, and turned on the winch, till it appear to be of a uniform colour. The fire is then increaſed, and the bath is kept boiling for two hours, taking care to turn the ſilk occaſionally. The fire is afterwards put out, and the ſilk put into the bath, where it is allowed to remain for a few hours longer. It is then taken out, waſhed at the river, twice beetled, wrung, and dried. Two proceſſes are recommended by Scheffer and Macquer. In that of the former, a greater proportion of cochineal is employed in the dye-bath; but, in that of the latter, a yellow ground is previouſly communicated to the ſilk. The colour which is thus obtained reſiſts the action of ſoap, and is more durable than that which is produced by means of carthamus.

Poppy-red.

214. To obtain other ſhades of red, the above proceſſes muſt be varied. If, after the ſilk has been wrung out of the ſolution of tin, it is ſteeped for a night in a cold ſolution of alum, in the proportion of one ounce to a quart of water, wrung and dried, then waſhed and boiled with cochineal, it will only appear of a pale poppy-colour; but a fine poppy-red may be produced by ſteeping it twelve hours in the ſolution of tin, diluted with eight parts of water, then left all night in the ſolution of alum, waſhed, dried, and paſſed through two baths of cochineal, taking care to add to the ſecond bath a ſmall quantity of ſulphuric acid. The ſame colour may be produced by dyeing the ſilk previouſly with anotta, and then paſſing it ſucceſſively through a number of baths prepared with an alkaline ſolution of carthamus, to which lemon juice has been added, till it acquire a fine cherry-colour. To brighten the colour, the ſilk, after being dyed, may be immerſed in hot water acidulated with lemon juice.

Cherry red, &c.

215. Other ſhades of red, as a cherry-red, and fleſh-red, are alſo produced by means of carthamus. For a cherry-red, it is not neceſſary that the ſtuff be previouſly dyed with anotta, and the proportion of colouring matter is ſmaller. A fleſh-red colour is obtained by adding a little ſoap to the bath, which has the effect of ſoftening the colour, and of retarding the action of the colouring matter on the ſtuff. To produce dark ſhades, it is ſometimes uſual to mix archil, and by this means the expence is diminiſhed.

Scarlet.

216. Thoſe who have produced a colour on ſilk which comes neareſt to ſcarlet, Berthollet obſerves, begin with dyeing the ſilk crimſon. It is then dyed with carthamus, and laſtly it is dyed yellow without heat. By this proceſs a fine colour is obtained; but the dye of the carthamus is not permanent, as it is deſtroyed by the action of the air, and the colour becomes deeper. The following is Dr Bancroft's proceſs. In a ſolution of murio-ſulphate of tin, diluted with five times its weight of water, the ſilk is to be ſoaked for two hours; and after being taken out, it is to be wrung and partially dried. It is then to be dyed in a bath prepared with four parts of cochineal, and three of quercitron bark. In this way a colour approaching to ſcarlet is obtained. To give the colour more body, the immerſion may be repeated both in the ſolution of tin, and in the dyeing bath; and the brightneſs of the ſcarlet is increaſed by means of the addition of carthamus. A lively roſe colour is produced by omitting the quercitron bark, and dyeing the ſilk with cochineal only; and by adding a large proportion of water to the cochineal, a yellow ſhade is obtained, which changes the the cochineal to the compound ſcarlet colour *.

Roſe-colour.

4. *Of the Proceſs for dyeing Cotton and Linen Red.*

Madder red.

217. Madder is moſt commonly employed for dyeing cotton and linen a red colour; and indeed in this kind of dyeing it is the moſt uſeful of all colouring matters. The affinity of the colouring matter of madder for cotton is ſtronger than for linen; but it has been found that the proceſſes which are moſt ſucceſsful in dyeing the one are the moſt preferable for the other. There are two kinds of madder reds: the one is called *ſimple* madder red; and the other, which is much brighter, has been diſtinguiſhed by the name of *Turkey* or *Adrianople* red, becauſe it comes from the Levant, and has rarely been equalled in brightneſs and permanency. In communicating this beautiful red colour to cotton, by means of madder, a great many uſeleſs and ridiculous directions have been given. According to ſome proceſſes, the period of a month is ſcarcely ſufficient to finiſh all the operations which are conſidered as indiſpenſibly neceſſary for obtaining this dye.

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* *Phil. of Perm. Col.* 312.

Mordants for madder red.

218. The principal mordants which are employed in dyeing cotton with madder, are oil, gall-nuts, and alum. The colouring matter of madder cannot be fixed on cotton, till the latter has been impregnated with oil. A cold ſoapy liquor is formed by a combination of oil and a weak ſolution of ſoda. By the uſe of this alkaline ley the oil is diluted and divided, and can be eaſily and equally applied to all the parts of the cotton. According to Chaptal, potaſh produces the ſame effect as ſoda; and attention to this is of ſome importance, from the difference of price of the two ſubſtances. All kinds of ſoda or oil are not fit for this preliminary preparation. The ſoda muſt be in the cauſtic ſtate, and its cauſticity muſt be the effect of calcination; becauſe if it has been rendered cauſtic by means of lime, it becomes of a brown colour. The ſoda alſo ſhould contain little muriate, for when this neutral ſalt prevails, the combination of the oil and the ſoda is greatly retarded. The moſt proper oil is not of a fine kind, but that which contains a large portion of the extractive principle. As the ley of ſoda is only employed for the purpoſe of diluting and conveying the oil equally to all the parts of the cotton, there muſt be a perfect combination of the oil and the ſoda. Indeed this is of ſo much importance, that many place the whole ſecret of a ſtrong colour in the choice of good oil and ſoda. From this it follows, that the oil ſhould be in exceſs, otherwiſe it would abandon the ſtuff in waſhing, and the colour would remain dry.

Uſes of galling.

219. The cotton, being impregnated with oil, is ſubjected to the operation of galling. The uſe of gall-nuts is attended with ſeveral advantages. 1. The gallic acid which they contain decompoſes the ſaponaceous liquor with which the cotton is impregnated, and fixes the oil on the ſtuff. 2. The other properties which the galls poſſeſs, prediſpoſe the cotton to receive the colouring matter. 3. The aſtringent principle unites with the oil, and forms with it a compound, which on drying becomes black, is not very ſoluble in water, and has a ſtrong affinity with the colouring matter of madder.

Practical remarks.

220. From theſe principles ſome practical obſervations may be deduced. 1. Gall nuts furniſh the moſt proper aſtringent matter for this kind of dye. 2. To effect a ſpeedy and perfect decompoſition, the galls ought to be ſtrained as hot as poſſible. 3. The galled cotton ſhould be ſpeedily dried, for otherwiſe it might aſſume a black colour, which would injure the brightneſs of the red. 4. The proceſs of galling ſhould be performed in dry weather, becauſe when the weather is moiſt, the aſtringent principle produces a black colour, and dries ſlowly. 5. The cotton ſhould be preſſed together with great care, that the decompoſition may be equally effected at every point of the ſurface. 6. It is neceſſary to attend to the proportion between the gall nuts and the ſoap, for if the former predominate, the colour is black, and if the ſoap is in exceſs, the portion of oil uncombined with the aſtringent principle eſcapes in the waſhings, and impoveriſhes the colour.

Alum as a mordant.

221. Alum is alſo employed as a mordant in dyeing cotton red. This ſubſtance not only heightens the red of madder, but contributes alſo, by its decompoſition, and the fixation of its alumina, to give ſolidity to the colour. When cotton, after it has been galled, is immerſed in a ſolution of alum, it immediately changes its colour, and becomes gray. No precipitate appears in the bath, becauſe the operation takes place in the tiſſue of the cloth itſelf. But if the ſolution of alum be employed at too high a temperature, part of the galls eſcapes from the ſtuff, and the decompoſition of the alum is then effected in the bath. This, which ſhould be guarded againſt, muſt obviouſly diminiſh the proportion of the mordant, and render the colour poorer.

Application of the mordant.

222. This mordant, which is the moſt complicated known in dyeing, requires great attention in its application. In this, indeed, conſiſts the whole difficulty of dyeing cotton a madder or Turkey red. In this mordant there is a combination of three principles, oil, the aſtringent principle, and alumina; and on their proper combination, the perfection of the colour depends. When any one of them is employed ſeparately, the colour is neither ſo bright, nor ſo completely fixed.

Proceſs for dyeing red at Aſtracan.

223. After theſe preliminary obſervations, we ſhall now give a fuller detail of ſome of the proceſſes which are followed in dyeing cotton Turkey red. The following is that which is practiſed at Aſtracan, of which an account has been given by Profeſſor Pallas.

Preparation.

"The cotton to be dyed red is firſt waſhed exceedingly clean in running water, and, when the weather is clear, hung up on poles to dry. If it does not dry before the evening, it is taken into the houſe, on account of the ſaline dews ſo remarkable in the country around Aſtracan, and again expoſed to the air next morning. When it is thoroughly dry it is laid in a tub, and fiſh-oil is poured over it till it is entirely covered. In this ſtate it muſt ſtand all night, but in the morning it is hung up on poles, and left there the whole day; and this proceſs is repeated for a week, ſo that the cotton lies ſeven nights in oil, and is expoſed ſeven days to the atmoſphere, that it may imbibe the oil and free itſelf from all air. The yarn is then again carried to a ſtream, cleaned as much as poſſible, and hung up on poles to dry.

The mordant.

224. "After this preparation a mordant is made of three materials, which muſt give the grounds of the red colour. The pulverized leaves of the ſumach are firſt boiled in copper kettles; and when their colouring matter has been ſufficiently extracted, ſome powdered galls are added, with which the liquor muſt be again boiled; and by theſe means it acquires a dark dirty colour. After it has been ſufficiently boiled the fire is taken from under the kettle, and alum put into the liquor yet hot, where it is ſoon diſſolved. The proportion of theſe three ingredients I cannot determine with ſufficient accuracy, becauſe the dyers make uſe of different quantities at pleaſure. The powder of the ſumach leaves is meaſured into the kettle with ladles; the water is poured in according to a gauge, on which marks are made to ſhew how high the water muſt ſtand in the kettle to ſoak ſix, eight, ten, &c. puds of cotton yarn. The galls and alum are added in the quantity of five pounds to each pud of cotton. In a word, the whole mordant muſt be ſufficiently yellow, ſtrong, and of an aſtringent taſte.

225. "As ſoon as the alum is diſſolved, no time muſt be loſt in order that the mordant may not be ſuffered to

to cool. The yarn is then put into hollow blocks of wood ſhaped like a mortar, into each of which ſuch a quantity of the mordant has been poured as may be ſufficient to moiſten the yarn without any of it being left. As ſoon as the workman throws the mordant into the mortar, he puts a quantity of the yarn into it, and preſſes it down with his hand till it becomes uniformly moiſtened, and the whole cotton yarn has ſtruck. By this it acquires only a pale yellow colour, which however is durable. It is then hung up on poles in the ſun to dry, again waſhed in the ſtream, and afterwards dried once more.

226. "By the yellow dye of the ſumach leaves, the madder dye becomes brighter and more agreeable; but the galls damp the ſuperfluous yellow, and together with the alum prepare the yarn for its colour. Some dyers however omit the uſe of theſe leaves altogether, and prepare their mordant from galls and alum only, by firſt boiling the galls in due proportion with the requiſite quantity of water, then diſſolving the alum with boiling water in a ſeparate veſſel, afterwards pouring both liquors together into a tub, and ſuffering the cotton to remain in them an hour, or an hour and a half; after which it is dried gradually, then waſhed, and again dried once more. By this proceſs the yarn acquires a dirty reddiſh colour.

Madder dye.

227. "The next part of the proceſs is to prepare the madder dye. The madder, ground to a fine powder, is ſpread out in large troughs, and into each trough is poured a large cup full of ſheep's blood, which is the kind that can be procured with the greateſt facility by the dyers. The madder muſt be ſtrongly mixed in it by means of the hand, and then ſtand ſome hours in order to be thoroughly ſoaked by it. The liquor then aſſumes a dark red appearance, and the madder in boiling yields more dye.

228. "After this proceſs water is made hot in large kettles, fixed in brick-work; and as ſoon as it is warm the prepared red dye is put into it, in the proportion of a pound to every pud of cotton. The dye is then ſuffered to boil ſtrongly; and when it is boiled enough, which may be tried on cotton threads, the fire is removed from under the kettle, and the prepared cotton is depoſited near it. The dyer places himſelf on the edge of the brick-work that encloſes the kettle; dips the cotton yarn, piece by piece, into the dye; turns it round, backwards and forwards; preſſes it a little with his hands; and lays each piece, one after the other, in pails ſtanding ready for the purpoſe. As ſoon as all the cotton has received the firſt tint, it is hung up to dry: as the red, however, is ſtill too dull, the yarn which has been already dyed once, and become dry, is put once more into the dyeing-kettle, and muſt be left there to ſeethe for three hours over a ſtrong fire, by which it acquires that beautiful dark red colour which is ſo much eſteemed in the Turkey yarn. The yarn is now taken from the dye with ſticks; the ſuperfluous dye which adheres to it is ſhaken off; the hanks are put in order, and hung up, one after another, to dry. When it is thoroughly dry, it is waſhed in the pure ſtream and again dried. The only fault of the Aſtracan dyers is, that the colour is ſometimes brighter and ſometimes darker, probably becauſe they do not pay ſufficient attention to the proportions, or becauſe the madder is not always of the ſame goodneſs.

Boiling in ley of ſoda.

229. "In the laſt place, the above-mentioned ſoda (kalakar) is diſſolved with boiling water in tubs deſtined for that purpoſe, and it is uſual here to allow twenty pounds of ſoda to forty pounds of cotton, or half the weight. Large earthen jars, which are made in Perſia of very ſtrong clay, a yard and a half in height, almoſt five ſpans wide in the belly, and ending in a neck a ſpan and a half in diameter, encloſed by means of cement in brick-work over a fire-place, in ſuch a manner that the necks only appear, are filled with the dyed cotton yarn. The ley of diſſolved ſoda, which is blackiſh and very ſharp, is then poured over it till the jars be filled; and ſome clean rags are preſſed into their mouths, that the uppermoſt ſkains of yarn may not lie uncovered. A fire is then made in the fire-place below, and continued for 24 hours; and in the mean time the ſteam which ariſes from the jars is ſeen collected among the rags in red drops. By this boiling the dye is ſtill more heightened, and is made to ſtrike completely; every thing ſuperfluous is removed, and all the fat matter which ſtill adheres to the yarn is waſhed out: nothing more is then neceſſary for completing the dye of the yarn but to rinſe it well ſeveral times in running water, and then to dry it.

The ſame colour by other means.

230. "That the dye of madder might be made very penetrating by other methods, and through the means of other oily and reſinous ſubſtances, is ſhewn by the proceſs of the Tunguſians to dye horſe, goat's and reindeer's hair, which they uſe for ornamenting their dreſſes, of a beautiful red colour, with the roots of the croſs-wort, or northern madder (*galium*), and narrow-leaved woodroof (*aſperula tinctoria*), which have a reſemblance to thoſe of madder. They boil the freſh or dried roots with about the ſame quantity of agaric (*agaricus officinarum*), which, as is well known, is abundant in reſinous gummy particles, and is uſed by the people of Jakut inſtead of ſoap; they then lay in it the white hair which they wiſh to dye, and ſuffer it to ſeethe ſlowly until it be ſufficiently red. Cotton cloth is dyed with madder at Aſtracan in the ſame manner: but many purſue a fraudulent proceſs, by dyeing with red wood, and then ſell their cloth as that which has been dyed in the proper manner."

The Grecian method.

231. The proceſſes which are employed in the Grecian manufactories for dyeing Turkey red, as they have been deſcribed by C. Felix, in a memoir in the French annals of chemiſtry, are ſomewhat different from the above. "In theſe manufactories," he obſerves, "the workmen dye at one time a maſs of ſkains weighing thirty-five occas (K); each occa being equal to about fifty ounces. The firſt proceſs is that of cleaning the cotton, for which purpoſe three leys are employed; one of ſoda, another of aſhes, and a third of lime. The cotton is thrown into a tub, and moiſtened with the liquor of the three leys in equal quantities; it is then boiled in pure water, and waſhed in running water.

Preparation.

(K) Equal to 109lb. 6oz.

Second bath.

232. “ The ſecond bath given to the cotton is compoſed of ſoda and ſheep's dung diſſolved in water. To facilitate the ſolution, the ſoda and dung are pounded in a mortar. The proportions of theſe ingredients employed, are, one occa of dung, ſix of ſoda, and forty of water. When the ingredients are well mixed, the liquor expreſſed from them is ſtrained, and being poured into a tub, ſix occas of olive oil are added to it, and the whole is well ſtirred till it becomes of a whitiſh colour, like milk. The cotton is then beſprinkled with this water, and when the ſkains are thoroughly moiſtened, they are wrung, preſſed, and expoſed to dry. The ſame bath muſt be repeated three or four times, becauſe it is this liquor which renders the cotton more or leſs fit for receiving the dye. Each bath is given with the ſame liquor, and ought to continue five or ſix hours. It is to be obſerved that the cotton, after each bath, muſt be dried without being waſhed, as it ought not to be rinſed till after the laſt bath. The cotton is then as white as if it had been bleached in the fields.

233. “ The bath of ſheep's dung is not uſed in our manufactories (L); it is a practice peculiar to the Levant. It may be believed that the dung is of no utility for fixing the colours; but it is known that this ſubſtance contains a great quantity of volatile alkali, in a diſengaged ſtate, which has the property of giving a roſy hue to the red. It is therefore probable that it is to this ingredient that the red dyes of the Levant are indebted for their ſplendour and vivacity. This much, at any rate, is certain, that the Morocco leather of the Levant is prepared with dog's dung; becauſe it has been found that this dung is proper for heightening the colour of the black. The bath of dung is followed by the proceſs of galling.

Galling and aluming.

234. “ The galling is performed by immerſing the cotton in a bath of warm water, in which five occas of pulveriſed gall-nuts have been boiled. This operation renders the cotton more fit for being ſaturated with the colour, and gives to the dye more body and ſtrength. After the galling comes aluming, which is performed twice, with an interval of two days, and which conſiſts in dipping the cotton into a bath of water in which five occas of alum have been infuſed, mixed with five occas of water alkalized by a ley of ſoda. The aluming muſt be performed with care, as it is this operation which makes the colouring particles combine beſt with the cotton, and which ſecures them in part from the deſtructive action of the air. When the ſecond aluming is finiſhed, the cotton is wrung; it is then preſſed, and put to ſoak in running water, after being incloſed in a bag of thin cloth.

Dyeing.

235. “ The workmen then proceed to the dyeing.—To compoſe the colours they put in a kettle five occas of water and thirty-five occas of a root which the Greeks call *ali-zari*, or painting colour, and which in Europe is known under the name of *madder*. The madder, after being pulveriſed, is moiſtened with one occa of ox or ſheep's blood. The blood ſtrengthens the colour, and the doſe is increaſed or leſſened according to the ſhade of colour required. An equal heat is maintained below the kettle, but not too violent; and when the liquor ferments, and begins to grow warm, the ſkains are then gradually immerſed, before the liquor becomes too hot. They are then tied with packthread to ſmall rods, placed croſſwiſe above the kettle for that purpoſe, and when the liquor boils well, and and in an uniform manner, the rods from which the ſkains were ſuſpended are removed, and the cotton is ſuffered to fall into the kettle, where it muſt remain till two-thirds of the water is evaporated. When one-third only of the liquor remains, the cotton is taken out and waſhed in pure water.

Alkaline bath.

236. “ The dye is afterwards brought to perfection by means of a bath alkalized with ſoda. This manipulation is the moſt difficult and the moſt delicate of the whole, becauſe it is that which gives the colour its tone. The cotton is thrown into this new bath, and made to boil over a ſteady fire till the colour aſſumes the required tint. The whole art conſiſts in catching the proper degree: a careful workman, therefore, muſt watch with the utmoſt attention for the moment when it is neceſſary to take out the cotton, and he will rather burn his hand than miſs that opportunity. It appears that this bath, which the Greeks think of ſo much importance, might be ſupplied by a ley of ſoap; and it is probable that ſaponaceous water would give the colour more brightneſs and purity.

Methods of improving the colour.

237. “ When the colour is too weak, the Levantines know how to ſtrengthen it by increaſing the doſe of the colouring ſubſtances; and when they wiſh to give it brightneſs and ſplendour, they employ different roots of the country, and, in particular, one named *ſaſſari*, ſpecimens of which I have ſent to France. The alizari, which is the principal colouring matter employed in the Greek dye-houſes, is collected in Natolia, and is brought to Greece from Smyrna: ſome of it comes alſo from Cyprus and Meſopotamia. The ſuperiority of this Levantine plant to the European madder is acknowledged by all thoſe acquainted with the art of dyeing, and may ariſe from two cauſes; the manner in which it is cultivated, and the method employed for its deſiccation (M)”.

238. To

(L) The French manufactories.

(M) “ The chief manufactories,” continues our author, “ for dyeing ſpun cotton red, eſtabliſhed in Greece, are in Theſſaly. There are ſome at Baba, Rapſani, Tournavos, Lariſſa, Pharſalia, and in all the villages ſituated on the ſides of Oſſa and Pelion. Theſe two mountains may be conſidered as the alembics that diſtil the eternal vapours with which Olympus is crowned, and which diſtribute them throughout the beautiful valleys ſituated around them. Of theſe valleys, that of Tempe has at all times been diſtinguiſhed by the beauty of its ſhady groves and of its ſtreams. Theſe ſtreams, on account of their limpidneſs, are very proper for dyeing, and ſupply water to a great number of manufactories, the moſt celebrated of which are thoſe of Ambelakia.

“ Ambelakia, on account of the activity which prevails in it, has a greater reſemblance to a town of Holland than a village of Turkey. This village, by its induſtry, communicates life and activity to all the neighbouring country, and gives birth to an immenſe trade, which connects Germany with Greece in a thouſand ways. Its

population,

Papillon's proceſs.

238. To theſe proceſſes we ſhall add the account of another, which was long ſucceſsfully practiſed at Glaſgow by Mr Papillon, a native of France, and was communicated by him, for a ſuitable premium, to the commiſſioners and truſtees for manufactures in Scotland, to be by them publiſhed for the benefit of the public, at the end of a certain term of years. This tranſaction took place in 1790, and the period having expired, the truſtees announced it to the public in 1803. The proceſs, which conſiſts of nine different ſteps, is the following.

Step I.

For 100 lib. cotton you muſt have
100 lib. of alicante barilla,
20 lib. of pearl aſhes,
100 lib. quicklime.

The barilla is mixed with ſoft water in a deep tub, which has a ſmall hole near the bottom of it, ſtopped at firſt with a peg.—This hole is covered in the inſide with a cloth ſupported by two bricks, that the aſhes may be prevented from running out at it, or ſtopping it up while the ley filters through it.

Under this tub is another to receive the ley; and pure water is repeatedly paſſed through the firſt tub to form lees of different ſtrength, which are kept ſeparate at firſt until their ſtrength is examined. The ſtrongeſt required for uſe muſt ſwim or float an egg, and is called the ley of ſix degrees of the French Hydrometer, or Peſeliqueur. The weaker are afterwards brought to this ſtrength, by paſſing them through freſh barilla. But a certain quantity of the weak, which is of 2 degrees of the above hydrometer, is reſerved for diſſolving the oil, and gum, and the ſalt, which are uſed in ſubſequent parts of the proceſs. This ley of 2 degrees is called the weak barilla liquor, the other is called the ſtrong.

Diſſolve the pearl-aſhes in 10 pails, of 4 gallons each, of ſoft water, and the lime in 14 pails.

Let all the liquors ſtand till they become quite clear, and then mix 10 pails of each.

Boil the cotton in the mixture five hours, then waſh it in running water and dry it.

Step II. *Bainbie*, or *Gray Steep.*

Take a ſufficient quantity (20 pails) of the ſtrong barilla water in a tub, and diſſolve or dilute in it 2 pails full of ſheep's dung, then pour into it 2 quart bottles of oil of vitriol, and 1 lib. of gum arabic, and 1 lib. of ſal ammoniac, both previouſly diſſolved in a ſufficient quantity of the weak barilla water, and laſtly, 25 lib of olive oil, which has been previouſly diſſolved or well mixed with 2 pails of the weak barilla water.

The materials of this ſteep being well mixed, tramp or tread down the cotton into it, until it is well ſoaked; let it ſteep 24 hours, and then wring it hard and dry it.

Steep it again 24 hours, and again wring and dry it.

Steep it a third time 24 hours, after which wring and dry it, and laſtly waſh it well and dry it.

Step III. *The White Steep.*

This part of the proceſs is preciſely the ſame with the laſt, in every particular, except that the ſheep's dung is omitted in the compoſition of the ſteep.

Step IV. *Gall Steep.*

Boil 25 lib. of galls bruiſed in 10 pails of river water, until 4 or 5 are boiled away; ſtrain the liquor into a tub, and pour cold water on the galls in the ſtrainer, to waſh out of them all their tincture.

As ſoon as the liquor is become milk warm, dip your cotton hank by hank, handling it carefully all the time, and let it ſteep 24 hours.

Then wring it carefully and equally, and dry it well without waſhing.

Step V. *Firſt Alum Steep.*

Diſſolve 25 lib. of Roman alum in 14 pails of warm water, without making it boil, ſkim the liquor well, and add 2 pails of ſtrong barilla water, and then let it cool until it be lukewarm.

Dip your cotton and handle it hank by hank, and let it ſteep 24 hours, and wring it equally and dry it well without waſhing.

Step VI. *Second Alum Steep,*

Is performed in every particular like the laſt, but after the cotton is dry, you ſteep it 6 hours in the river, and waſh and dry it.

Step.

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population, which has been tripled within theſe fifteen years, amounts at preſent to 4000, and all theſe people exiſt by dyeing. None of thoſe vices or cares produced by idleneſs are known here. The hearts of the inhabitants are pure, and their countenances unclouded. Servitude, which degrades the countries watered by the Peneus, has not yet aſcended to theſe hills: no Turk can reſide or live among theſe people; and they govern themſelves, like their anceſtors, by their *protoyeros* and their own magiſtrates. Twice have the ſavage muſſulmans of Lariſſa, envious of their eaſe and happineſs, attempted to ſcale their mountains in order to plunder their houſes; and twice have they been repulſed by hands which ſuddenly quitted the ſhuttle to aſſume the muſket.

"All hands, and even thoſe of the children, are employed in the dye-houſes of Ambelakia; and while the men dye the cotton, the women are ſpinning and preparing it. The uſe of wheels is not known in this part of Greece; all the cotton is ſpun on a diſtaff: the thread, indeed, is certainly not ſo round or equal, but it is ſofter, more ſilky, and more tenacious; it is leſs apt to break, and laſts longer; it is alſo more eaſily whitened, and more proper for being dyed. It is a pleaſing ſpectacle to ſee the women of Ambelakia, each ſpinning from a diſtaff, and ſitting converſing together on the threſhold of their doors; but as ſoon as a ſtranger appears, they inſtantly retire and conceal themſelves in their houſes, manifeſting, like Galatea, in their precipitate retreat, a deſire of flying and of ſhewing themſelves:—

Et fugit ad ſalices, et ſe cupit ante videri."

STEP VII. *Dyeing Steep.*

The cotton is dyed by about 10 lib. at once, for which take 2½ gallons of ox blood, and mix it in the copper with 28 pails of milk warm water, and ſtir it well; then add 25 lib. of madder, and ſtir all well together. Then having beforehand put the 17 lib. of cotton on ſticks, dip it into the liquor, and move and turn it conſtantly one hour, during which you gradually increaſe the heat, until the liquor begin to boil at the end of the hour. Then ſink the cotton, and boil it gently one hour longer; and, laſtly, waſh it and dry it.

Take out ſo much of the boiling liquor, that what remains may produce a milk-warm heat with the freſh water with which the copper is again filled up, and then proceed to make up a dyeing liquor as above, for the next 10 lib. of cotton.

STEP VIII. *The fixing Steep.*

Mix equal parts of the gray ſteep liquor, and of the white ſteep liquor, taking 5 or 6 pails of each. Tread down the cotton into this mixture, and let it ſteep ſix hours, then wring it moderately and equally, and dry it without waſhing.

STEP IX. *Brightening Steep.*

Ten lib. of white ſoap muſt be diſſolved moſt carefully and completely in 16 or 18 pails of warm water; if any little bits of the ſoap remain undiſſolved, they will make ſpots in the cotton. Add four pails of ſtrong barilla water, and ſtir it well. Sink your cotton in this liquor, keeping it down with croſs ſticks, and cover it up and boil it gently two hours, then waſh and dry it, and it is finiſhed.

VESSELS.

The number of veſſels neceſſary for this buſineſs is greater in proportion to the extent of the manufactory; but, in the ſmalleſt work, it is neceſſary to have four coppers of a round form.

1*ſt*, The largeſt, for boiling and for finiſhing, is 28 inches deep by 38 or 39 wide in the mouth, and 18 inches wider in the wideſt part.

2*d*, The ſecond, for dyeing, is 28 deep, by 23 or 24 in the mouth.

3*d*, The third, for the alum ſteep, is like the ſecond.

4*th*, The fourth, for boiling the galls, is 20 deep, by 28 wide.

A number of tubs or larger wooden veſſels are neceſſary, which muſt all be of fir, and hooped with wood or with copper.

Iron muſt not be employed in their conſtruction, not even a nail; but where nails are neceſſary, they muſt be of copper.

By the pail is always underſtood a wooden veſſel, which holds four Engliſh gallons, and is hooped with copper.

In ſome parts of the above proceſs, the ſtrength of the barilla liquor or liquors is determined, by telling to what degree a peſeliqueur or hydrometer ſunk in them.

The peſeliqueur is of French conſtruction. It is ſimilar to the glaſs hydrometer uſed by the ſpirit dealers in this country; and any artiſt who makes theſe inſtruments, will find no difficulty in conſtructing one with a ſcale ſimilar to that employed by M. Papillon, when he is informed of the following circumſtances:

1*ſt*, The inſtrument, when plunged in good ſoft water, ſuch as Edinburgh pipe water, at temperature 60 degrees ſinks to the 0, or beginning of the ſcale, which ſtands near the top of the ſtem.

2*d*, When it is immerſed in a ſaturated ſolution of common ſalt, at the ſame temperature of 60 degrees it ſinks to the 26th degree of the ſcale only, and this falls at ſome diſtance from the top of the ball.

This ſaturated ſolution is made by boiling in pure water, refined ſea or common ſalt, till no more is diſſolved, and by filtering the liquor when cold through blotting paper.

It ſhould alſo be obſerved, that whenever directions are given to dry yarn, to prepare it for a ſucceeding operation, that this drying ſhould be performed with particular care, and more perfectly than our dryeſt weather is in general able to effect. It is done therefore in a room heated by a ſtove to a great degree.

Hauſſmann's proceſs for madder red.

239. There is ſtill another proceſs, which is recommended by Hauſſmann, this proceſs, (ſays he) obtains a beautiful and durable red. He makes a cauſtic ley of one part of common potaſh diſſolved in four of boiling water, and a half part of quicklime, which is afterwards ſlaked in it. He then diſſolved one part of powdered alum in two of boiling water, and to this ſolution while it was yet warm, he added that of the cauſtic ley. The ſolution of alumina being left at reſt, formed, on cooling, a precipitate of ſulphate of potaſh. A 33d part of linſeed oil was then mixed with the alkaline ſolution of alumina, which then formed a milky ſaponaceous liquid. When the mixture is to be uſed, it ought to be well ſhaken, becauſe the oil ſeparates. The ſtuffs of cotton or linen muſt be ſucceſſively immerſed in it, and equally preſſed, and muſt be dried under ſhelter from rain in ſummer, and in a warm place in winter; and being left in that ſtate for 24 hours, are then waſhed in pure running water, and again dried. The ſame proceſs in the immerſion in alkaline ley is again to be repeated, taking care to introduce firſt thoſe ſtuffs which were laſt in the firſt ſolution. The whole of the mixture ſhould be conſumed each time, as it would attract carbonic acid from the air, and ſuffer the alumina to be precipitated.

240. Two immerſions in the alkaline ſolution of alumina mixed with linſeed oil, afford a beautiful red; but by impregnating the ſtuffs a third, or even a fourth time, in the ſame manner, the moſt brilliant colours are obtained. The intenſity of the colour is in proportion to the quantity of madder. A quantity of madder equal in weight to the ſtuffs, will yield a red, which, by clearing becomes of a roſy ſhade; and ſhades of crimſon of different degrees of brightneſs are obtained, by uſing two, three, or four times the weight of madder; but unleſs the water employed in the proceſſes contains ſome portion of lime, the addition of the chalk ſhould never be omitted.

Scarlet with cochineal.

241. The ſcarlet colour communicated to cotton by means of cochineal, is far from being permanent; but if this colour is wiſhed to be communicated to cotton, Dr Bancroft recommends to ſteep the cotton, previouſly moiſtened, for half an hour in a diluted ſolution of muria-

murio-ſulphate of tin, and then having wrung the cotton, to plunge it into water, in which as much potaſh has been diſſolved as will neutralize the acid adhering to the cotton, ſo that the oxide of tin may be more copiouſly fixed on the fibres of the cotton. The ſtuff being afterwards rinſed in water, may be dyed with cochineal and quercitron bark, in the proportion of four pounds of the former to two and a half or three pounds of the latter. A full bright colour is thus given to the cottou, which will bear ſlight waſhings with ſoap, and expoſure to the air. Indeed the yellow part of the colour derived from quercitron bark will bear long boiling with ſoap, and will reſiſt the action of acids.

Crimſon.

242. With the aluminous mordant, as it is uſually applied by callico printers for madder reds, cotton dyed with cochineal receives a beautiful crimſon colour, which will bear ſeveral waſhings, and reſiſt the weather for ſome time. It is not, however, to be conſidered as a fixed colour. Dr Bancroft is of opinion, that the addition of a ſmall portion of cochineal in dyeing madder reds upon the finer cottons, would be highly advantageous to the callico printers. By this addition the madder reds are rendered more beautiful, and the fawn colour, or browniſh yellow hue, which injures theſe reds, would be thus overcome. *.

SECT. II. *Of Yellow.*

243. In dyeing yellow, it is neceſſary to employ mordants, becauſe the affinity of yellow colouring matters for either animal or vegetable ſtuffs is not ſufficiently ſtrong to produce durable colours. Yellow colours, therefore, belong to that claſs which Dr Bancroft has denominated *adjective colours*. As in the former ſection, we ſhall firſt give a ſhort deſcription of the nature and properties of the ſubſtances employed in dyeing yellow, and then point out the moſt approved modes of communicating their colours to woollen, ſilk, cotton, and linen ſtuffs.

The ſubſtances capable of giving a yellow colour to different ſtuffs are very numerous; they do not all produce ſimilar quantities of colouring matter; their dye is not equally free; the colours they impart incline more or leſs to orange or green; they poſſeſs various degrees of brightneſs and permanency, and differ conſiderably in price; circumſtances by which the choice of the dyer ought always to be regulated. But thoſe commonly employed in dyeing yellow, are weld, fuſtic, anotta, and quercitron bark.

I. *Of the Subſtances employed in dyeing Yellow.*

Subſtances employed in dyeing yellow. Weld.

244. Weld (*reſeda luteola*, Lin.) is a plant which grows wild in Britain, and in different European countries. Its leaves are long, narrow, and of a bright green, but the whole plant is made uſe of in the dyeing of yellow. There are two kinds of weld, cultivated and wild, the former of which is deemed more valuable than the latter, as it yields a much greater proportion of colouring matter. When this plant is fully ripe, it is pulled, dried, and bound up in bundles for the uſe of the dyer. The wild ſpecies grows higher and has a ſtronger ſtalk than that which is cultivated, by which the one may be readily diſtinguiſhed from the other.

Properties.

245. A ſtrong decoction of weld is of a browniſh yellow colour, and if very much diluted with water, the colour, inclines to a green. An alkali gives to this decoction a deeper colour, and the precipitate it occaſions is not ſoluble in alkalies. Moſt of the acids give it a paler tinge, occaſioning a little precipitate which is ſoluble in alkalies. Alumina has ſo ſtrong an affinity for the colouring matter of weld, that it can even abſtract it from ſulphuric acid, and the oxide of tin produces a ſimilar effect. The greater part of metallic ſalts throw down ſimilar precipitates, which vary in their ſhades of colour according to the metal employed. A ſolution of common ſalt renders the liquor turbid, and a ſolution of tin yields a copious yellow precipitate, while the liquor long continues turbid, and ſlightly coloured.

Fuſtic.

246. Fuſtic (*morus tinctoria*, Lin.) is procured from a tree of conſiderable magnitude, which grows in the Weſt Indies. The wood is yellow, as its name imports, with orange veins. Ever ſince the diſcovery of America it has been uſed in dyeing, as appears from a paper in the Tranſactions of the Royal Society, of which Sir William Petty was the author. Its price is moderate, the colour it imparts is permanent, and it readily combines with indigo, which properties give it a claim to attention as a valuable ingredient in dyeing. Before it can be employed as a dye-ſtuff, it muſt be cut into chips and put in a bag, that it may not fix in, and tear the ſtuff, to which it is to impart its colouring matter.

Properties.

247. When a decoction of yellow wood or fuſtic is made very ſtrong, the colour is of a reddiſh yellow, and when diluted it is of an orange yellow. which it readily yields to water. It becomes turbid by means of acids, its colour is of a pale yellow, and the greeniſh precipitate may be re-diſſolved by alkalies. The ſulphates of zinc, iron, and copper, as well as alum, throw down precipitates compoſed of the colouring matter and the different baſes of the ſalts employed.

In examining the cauſes of the fixity of yellow colours, obtained from vegetables, Chaptal diſcovered that the durability of the pale yellow depended on the tanning principle, which is found united with the yellow colouring matter. He obtained by analyzing fuſtic, 1. A reſinous or gummy matter, which can communicate a beautiful yellow colour. 2. An extractive matter, which is alſo yellow, and affords a beautiful colour. 3. A tanning principle of a pale yellow colour, which becomes black by boiling, or expoſure to the air. This latter diminiſhes the brilliancy of the two former; but it may be ſeparated by a ſimple proceſs. Chaptal boiled with the wood ſome animal ſubſtance containing gelatinous matter, ſuch as bits of ſkin, ſtrong glue, &c. The tanning principle was thus precipitated with the gelatinous matter, and the bath held in ſolution only the colouring matters which yield a bright, full yellow; and by means of this proceſs he procured colours from ſeveral vegetables, equally bright with thoſe which are communicated by yellow wood and quercitron bark *.

Anotta.

248. Anotta is a ſpecies of paſte of a red colour, obtained from the berries of the *bixa orellana* Lin. which is a native of America. The anotta of commerce is imported from America to Europe in cakes of two or three lib. weight, where it is prepared from the ſeeds of the tree mentioned above; but the Americans are ſaid to be in poſſeſſion of a ſpecies of anotta ſuperior to that which they export, both for the brilliancy and

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* *Phil. of Perm. Col.* 317.

* *Phil. Mag.* i. 430.

and permanency of the colour it imparts. They bruiſe the ſeeds with their hands moiſtened with oil, ſeparating with a knife the paſte as it is formed, and drying it in the ſun; but the ſeeds are pounded with water when deſigned for ſale, and allowed to undergo the proceſs of fermentation.

Properties.

247. Anotta yields its colouring matter more readily to alcohol than to water, on which account it is uſed in yellow varniſhes to which an orange tinge is intended to be given. Acids form a precipitate with a decoction of anotta of an orange colour, which is ſoluble in alkalies; but ſolutions of common ſalt produce no ſenſible change. It yields an orange precipitate with a ſolution of alum, and the ſulphates of copper and iron produce effects of nearly a ſimilar nature. With a ſolution of tin the precipitate is of a lemon colour, and ſlowly depoſited.

Quercitron bark.

Phil. of Perm. Col. 319.

248. Quercitron, as it is denominated by Dr Bancroft, is the *quercus nigra* of Linnæus, and is a large tree which grows ſpontaneouſly in North America. The bark of it yields a conſiderable quantity of colouring matter, which was firſt diſcovered by Dr Bancroft in the year 1784, in whom the uſe and application of it in dyeing were excluſively veſted for a certain term of years by virtue of an act of parliament. To prepare it for uſe, the epidermis is taken off and pounded in a mill, the reſult of which proceſs is a number of filaments and a fine light powder; but as theſe do not contain equal quantities of colouring matter, it will be proper to employ them in their natural proportions.

Properties.

249. Quercitron bark readily imparts its colouring matter to water at 100° of Fahrenheit, which is of a yellowiſh brown, capable of being darkened by alkalies, and brightened by acids. With muriate of tin the precipitate is copious, and of a yellow colour; with ſulphate of tin it is a dark olive; and with ſulphate of copper it is yellow, but inclining to an olive. Nitro-muriate of tin yields a yellow extremely beautiful, probably owing to the oxide of tin combining with the colouring matter in a greater proportion than ſome other ſalts.

Other ſubſtances.

250. Beſides the ſubſtances already mentioned as employed in the dyeing of yellow, we may add ſaw-wort to the number (*ſerratula tinctoria*, Lin.) a plant which yields a colouring matter nearly ſimilar to that of weld, and may of conſequence be uſed as a proper ſubſtitute. Dyers broom (*geniſta tinctoria*) produces a yellow of very indifferent nature, and is therefore only employed in dyeing ſtuffs of the coarſeſt kind. Turmeric (*curcuma longa*) is a native production both of the Eaſt and Weſt Indies, and yields a more copious quantity of colouring matter than any other yellow dye-ſtuff; but it will probably never be of any eſſential ſervice in dyeing yellow, as no mordant has yet been diſcovered, capable of giving permanency to its colour.

251. Chamomile (*anthemis tinctoria*) yields a faint yellow colour, the hue of which is not unpleaſant, but is far from being durable, and even mordants are not capable of fixing it. Sulphate of lime, tartar and alum, bid faireſt for ſucceſs.

252. Fenugreek (*trigonella fœnugræcum*) yields ſeeds which, when ground, communicate to ſtuffs a pale yellow of tolerable durability; and the beſt mordants are found to be alum and muriate of ſoda, or common ſalt. American hiccory (*juglans alba*) is a tree, the bark of which yields a colouring matter in every reſpect reſembling that of the *quercus nigra*, but in quantity greatly inferior. French berries (*rhamnus infectorius*) produce a tolerable yellow colour, but it is by no means permanent. When uſed in the proceſs of dyeing, they are to be employed in the ſame manner as weld. According to Scheffer, a fine yellow colour may be imparted to ſilk, thread and wool, by means of the leaves of the willow; but Bergman informs us that only the leaves of the ſweet willow (*ſalix pentandra*) are proper for producing a permanent colour, as a few weeks expoſure to the ſun extracts that which is produced by the colouring matter from the leaves of the common willow.

253. In Switzerland and in England, the ſeeds of purple trefoil are ſometimes employed in the art of dyeing, on which Vogler made a number of experiments, in order to aſcertain what colours they would produce: and he found that a fine deep yellow was afforded by a bath made of a ſolution of theſe ſeeds with potaſh; that ſulphuric acid yielded a light yellow, and ſulphate of copper or blue vitriol, a yellow inclining to green. M. Dizé informs us, that the ſeeds of trefoil impart to wool a beautiful orange, and to ſilk a greeniſh yellow; and that while aluming is neceſſary in the proceſs of dyeing with the ſeeds of trefoil, a ſolution of tin cannot be employed.

II. *Of the Proceſſes for Dyeing Wool Yellow.*

With weld.

254. In dyeing woollen ſtuffs with weld, the mordants employed are alum and tartar, and by their means a pure, permanent yellow is obtained. The boiling is to be conducted in the uſual way; and according to Hellot, four ounces of alum to one ounce of tartar are to be employed. Other dyers, however, employ half as much tartar as alum. The colour is rendered paler, but more lively, by means of the tartar.

Preparation of the bath.

255. The bath is prepared by boiling the plant incloſed in a thin linen bag, and keeping it from riſing by means of a wooden croſs. Some boil it till it ſinks to the bottom of the veſſel, while others, after it is boiled, take it out, and throw it away. From three to four libs. of weld, and ſometimes leſs, are allowed for every lib. of ſtuff; but the quantity muſt be regulated by the intenſity of the ſhade deſired. Some dyers add a ſmall quantity of quicklime and aſhes, which are found to promote the extraction of the colouring matter. Theſe ſubſtances at the ſame time heighten the colour, but render it leſs ſuſceptible of reſiſting the action of acids.

For different ſhades.

256. With other additions, and different management, different ſhades may be obtained. Thus, lighter ſhades are produced by dyeing after deeper ones, adding water at each dipping, and keeping the bath at the boiling temperature. Theſe ſhades, however, are leſs lively than when freſh baths are employed, with a ſuitable proportion of weld. The addition of common ſalt or ſulphate of lime to the weld bath communicates a richer and deeper colour. With alum it is paler and more lively, with tartar ſtill paler, and with ſulphate of iron the ſhade inclines to brown. According to Scheffer, by boiling the ſtuff two hours, with one-fourth of its weight of a ſolution of tin, and the ſame proportion of tartar, and then waſhing and boiling it with an equal weight of weld, a fine yellow is produced; but if the ſtuff

ſtuff be in the ſtate of cloth, its internal texture is not penetrated. Poerner recommends a ſimilar preparation as for dyeing ſcarlet, and by theſe means the colour is brighter, more permanent, and lighter.

With quercitron bark.

257. Dr Bancroft recommends the quercitron bark as one of the cheapeſt and beſt ſubſtances for dyeing wool yellow. The following is the ſimple proceſs which he has propoſed for its application. The bark is to be boiled up with about its weight, or one-third more, of alum, in a ſuitable proportion of water, for about 10 minutes. The ſtuff previouſly ſcoured is then to be immerſed in the bath, taking care to give the higher colours firſt, and afterwards the paler ſtraw colours. By this cheap and expeditious proceſs, colours which are not wanted to be of a full or bright yellow, may be obtained. The colour may be conſiderably heightened by paſſing the unrinſed ſtuff a few times through hot water, to which a little clean powdered chalk, in the proportion of about 1½ lb. for each 100 lb. of ſtuff has been previouſly added. The bark, when uſed in dyeing, being firſt reduced to powder, ſhould be tied up in a thin linen bag, and ſuſpended in the liquor, ſo that it may be occaſionally moved through it, to diffuſe the colouring matter more equally.

Cheap proceſs.

Proceſs for permanent colours.

258. But although the above method poſſeſſes the advantages of cheapneſs and expedition, and is fully ſufficient for communicating pale yellows; to obtain fuller and more permanent colours, the common mode of preparation, by previouſly applying the aluminous mordant, ought to be preferred. The ſtuff, therefore, ſhould be boiled for about one hour or one hour and a quarter, with one-ſixth, or one-eighth of its weight of alum, diſſolved in a proper proportion of water. The ſtuff is then to be immerſed without being rinſed, into the dyeing bath, with clean hot water, and about the ſame quantity of powdered bark tied up in a bag, as that of the alum employed in the preparation. The ſtuff is then to be turned as uſual through the boiling liquor, until the colour appears to have acquired ſufficient intenſity. One pound of clean powdered chalk for every 100 lbs. of ſtuff is then to be mixed with the dyeing bath, and the operation continued for eight or ten minutes longer. This addition of the chalk raiſes and brightens the colour.

259. *Orange Yellow.*——To communicate a beautiful orange yellow to woollen ſtuffs, 10 lbs. of quercitron bark, tied up in a bag, for every 100 lb. of ſtuff are to be put into the bath with hot water. At the end of ſix or eight minutes, an equal weight of murio-ſulphate of tin is to be added, and the mixture well ſtirred for two or three minutes. The cloth, previouſly ſcoured, and completely wetted, is then immerſed in the dyeing liquor, and briſkly turned for a few minutes. By this proceſs the colouring matter fixes on the cloth ſo quickly and equally, that after the liquor begins to boil, the higheſt yellow may be produced in leſs than 15 minutes.

For different ſhades.

260. High ſhades of yellow, ſomewhat ſimilar to thoſe obtained from quercitron bark by the above proceſs, are frequently given with young fuſtic (*rhus cotinus*, Lin.) and dyers ſpirit, or nitro-muriate of tin; but this colour is much leſs beautiful and permanent, while it is more expenſive than what is obtained from the bark.

261. *Bright golden Yellow.*——This colour is produced by employing 10 pounds of bark for every 100 lbs. of cloth, the bark being firſt boiled a few minutes, and then adding ſeven or eight lbs. of murio-ſulphate of tin, with about five pounds of alum. The cloth is to be dyed in the ſame manner as in the proceſs for the orange yellow.

262. Bright yellows of leſs body are produced by employing a ſmaller proportion of bark, as well as by diminiſhing the quantity of murio-ſulphate of tin and alum. And indeed every variety of ſhade of pure bright yellow may be given by varying the proportions of the ingredients.

For greeniſh yellow.

263. To produce the lively delicate green ſhade, which, for certain purpoſes, is greatly admired, the addition of tartar, with the other ingredients, only is neceſſary, and the tartar muſt be added in different proportions, according to the ſhade which is wanted. For a full bright yellow, delicately inclining to the greeniſh tinge, it will be proper to employ eight pounds of bark, ſix of murio-ſulphate of tin, with ſix of alum, and four of tartar. An additional proportion of alum and tartar renders the yellow more delicate, and inclines it more to the green ſhade; but when this lively green ſhade is wanted in the greateſt perfection, the ingredients muſt be uſed in equal proportions. The delicate green lemon yellows are ſeldom required to have much fulneſs or body. Ten pounds of bark, therefore, with an equal quantity of the other ingredients, are ſufficient to dye three or four hundred pounds of ſtuffs *.

For pale green yellow.

264. To produce the exquiſitely delicate and beautiful pale green ſhades, the ſureſt method, Dr Bancroft obſerves, is to boil the bark with a ſmall proportion of water, in a ſeparate tin veſſel for ſix or eight minutes, and then to add the murio-ſulphate of tin, alum, and tartar, and to boil them together for about fifteen minutes. A ſmall quantity of this yellow liquor is then to be put into a dyeing veſſel, which has been previouſly ſupplied with water ſufficiently heated. The mixture being properly ſtirred, the dyeing proceſs is to be conducted in the uſual way, and the yellow liquor, as it is wanted, gradually added from the firſt veſſel. In this way, the moſt delicate ſhades of lively green lemon yellows are dyed with eaſe and certainty. Weld is the only dye-ſtuff from which ſimilar ſhades of colour can be obtained; but it is four times more expenſive. The yellows dyed from quercitron bark, Dr Bancroft adds, with murio-ſulphate of tin and alum as mordants, do not exceed the expence of one penny for each pound of ſtuff; beſides a conſiderable ſaving of time, labour, and fuel †.

Verdigriſe uſed for tartar.

265. A greeniſh ſhade may alſo be produced without tartar, by ſubſtituting verdigriſe diſſolved in vinegar, along with the bark; but it is neither ſo permanent, nor ſo bright and delicate, as that produced by means of tartar. Sulphate of indigo alſo, in very ſmall proportion, communicates a ſimilar ſhade, when it is employed with the bark, murio-ſulphate of tin, and alum; but it is apt to take unequally on the ſtuff, and beſides, in the language of the dyers, the colour has a tendency to *caſt* or *fly* in the finiſhing.

Cochineal and madder employed.

266. Small proportions of cochineal employed along with the bark and other ingredients, raiſe the colour to a beautiful orange, and even to an aurora. Madder may be alſo employed with the ſame view, for it heightens the yellow obtained from quercitron bark, although

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* *Bancroft*, 330.

† *Ibid.* 333.

although the colour thus obtained is inferior in beauty to that from cochineal. The madder may alſo be employed with weld for the ſame purpoſe †.

Colours from quercitron bark very durable.

267. The colours obtained from quercitron bark, by the proceſſes which we have now deſcribed, are very durable. They reſiſt the action of the air, of ſoap, and of acids. It is by the effects of alum, but eſpecially of tartar, that theſe colours become ſo fixed as to remain permanent by expoſure to the air. It is obſerved of the higheſt yellows, even when they approach to the orange, and which are beſt dyed, either with muriate, or murio-ſulphate of tin and bark, that although they reſiſt the action of ſoap and acids, they are apt to loſe their luſtre and become brown by the effect of the ſun and air; but this alſo happens to yellows dyed with nitro-muriate of tin, both with the bark and with weld, but in a ſtill greater degree with other yellow vegetable colouring matters. In ſome of theſe this defect is leſs eaſily obviated by alum and tartar, than it is in the yellow obtained from weld and quercitron bark ‡.

III. *Of the Proceſſes for Dyeing Silk Yellow.*

With weld.

268. To dye ſilk a plain yellow colour, the only ingredient which was formerly employed is weld. The following is the proceſs. The ſilk being previouſly ſcoured in the proportion of 20 lbs. of ſoap to the 100 of ſtuff, and then alumed and waſhed after the aluming, or as it is called, *refreſhed*, the bath is prepared with two pounds of weld for every pound of ſilk; and, having boiled for 15 minutes, it is to be paſſed into a vat through a ſieve or cloth. When the temperature is ſuch as the hand can bear, the ſilk is introduced, and turned, until it has acquired a uniform colour. While this operation is going on, the weld is to be boiled a ſecond time in freſh water; one half of the firſt bath is taken out, and its place ſupplied with a freſh decoction. The temperature of the freſh bath may be a little higher than the former, but it is neceſſary to guard againſt too great a degree of heat, that the colouring matter already fixed may not be diſſolved. The ſtuff is to be turned as before, and afterwards taken out of the bath. A quantity of ſoda is to be diſſolved in a part of the ſecond decoction, and a larger or ſmaller proportion of this ſolution is to be added to the bath, according to the intenſity of the ſhade required. When the ſilk has been turned a few times, a ſkain is wrung out, that it may be examined whether the colour be ſufficiently full, and have the proper golden ſhade. To render the colour deeper, and to give it the gold caſt, an addition of the alkaline ſolution is to be made to the bath, and to be repeated till the ſhade has acquired ſufficient intenſity. The alkaline ſolution may alſo be added along with the ſecond decoction of the weld, obſerving the precaution, that the temperature of the bath be never too great.

For a deeper colour.

For other ſhades.

269. To produce other ſhades of yellow, having more of a gold or jonquille colour, a quantity of anotta, proportioned to the ſhade required, is to be added to the bath, along with the alkali. Lighter ſhades of yellow, ſuch as pale lemon, or Canary-bird colour, are obtained, by previouſly whitening the ſilk, and regulating the proportion of ingredients in the bath by the ſhade required. To communicate a yellow having a tinge of green, a little indigo is added to the bath, if the ſilk has not been previouſly azured. To prevent the intenſity of the ſhade from being too great, the ſilk may be more ſlightly alumed than uſual.

A cheaper proceſs.

270. But, according to Dr Bancroft, the different ſhades of yellow obtained from weld, may be given to ſilk with equal facility and beauty, and at a cheaper rate, by employing quercitron bark as a ſubſtitute. A quantity of bark powdered and incloſed in a bag, in proportion to the ſhade of colour wanted, as from one to two pounds for every twelve pounds of ſilk, is put into the dyeing vat while the water is cold. Heat is then applied; and when it has become rather more than blood warm, or of the temperature of 100°, the ſilk having previouſly undergone the aluming proceſs, is to be immerſed and dyed in the uſual way. If a deep ſhade is wanted, a ſmall quantity of chalk or pearl-aſhes may be added towards the end of the operation. To produce a more lively yellow, a ſmall proportion of murio-ſulphate of tin may be employed; but it ſhould be cautiouſly uſed, as it is apt to diminiſh the luſtre of the ſilk. To produce ſuch a ſhade, the proportions of the ingredients may be four pounds of bark, three of alum, and two of murio-ſulphate of tin. Theſe are to be boiled with a proper quantity of water for ten or fifteen minutes; and the temperature of the liquid being ſo much reduced as the hand can bear it, the ſilk is immerſed and dyed as uſual, till it has acquired the proper colour. Care ſhould be taken to keep the liquor conſtantly agitated, that the colouring matter may be equally diffuſed *.

For an orange colour.

271. To dye ſilk of an aurora or orange colour, after being properly ſcoured, it may be immerſed in an alkaline ſolution of anotta, the ſtrength of which is to be regulated by the ſhade required; and the temperature of the bath ſhould be between tepid and boiling water. When the deſired ſhade has been obtained, the ſilks are to be waſhed and twice beetled, to free them from the ſuperfluous colouring matter, which would injure the beauty of the colour. When raw ſilk is to be dyed, that which is naturally white ſhould be ſelected, and the bath ſhould be nearly cold; for otherwiſe the alkali, by diſſolving the gum of the ſilk, deſtroys its elaſticity. Silk is dyed of an orange ſhade with anotta, but the ſtuffs muſt be reddened with vinegar, alum, or lemon juice. The acid, by ſaturating the alkali employed to diſſolve the anotta, deſtroys the yellow ſhade produced by the alkali, and reſtores its natural colour, which inclines to a red. But although beautiful colours are obtained by this proceſs, they do not poſſeſs any great degree of permanency.

Yellow dye from muſhrooms.

272. Several kinds of muſhrooms afford lively and durable yellow dyes. A bright ſhining dye of this deſcription has been extracted from the *boletus hirſutus*, which commonly grows on walnut and apple trees. The colouring matter is contained both in the tubular part, and alſo in the parenchyma of the body of the muſhroom. To extract the colouring matter, it is pounded in a mortar, and the liquor which is thus obtained, is boiled for a quarter of an hour in water. An ounce of liquor is ſufficient to communicate colouring matter to ſix pounds of water. After the liquor has been ſtrained, the ſtuff to be dyed is immerſed in it, and boiled for fifteen minutes. When ſilk is ſubjected to this proceſs, after being dyed, it is made to paſs through a bath of ſoft ſoap, by which it acquires a ſhining

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† *Bancroft*, 335.

‡ *Ibid.* 334.

* *Ibid.* 345.

ing golden yellow colour, which has a near reſemblance to the yellow of the ſilk employed to imitate embroidery in gold. This has been hitherto brought from China, and bears a very high price, the method of dyeing it being unknown in Europe. All kinds of ſtuff receive this colour, but it is leſs bright on linen and cotton, and ſeems to have the ſtrongeſt affinity for ſilk. The uſe of mordants, it is ſuppoſed, would modify and improve it greatly *.

* Phil. Mag. v. 100.

IV. *Of the Proceſſes for Dyeing Cotton and Linen Yellow.*

Proceſs with weld.

273. The proceſs which has been uſually followed in dyeing cotton and linen yellow, is by ſcouring it in a bath prepared in a ley with the aſhes of green wood. It is afterwards waſhed, dried, and alumed, with one-fourth of its weight of alum. After 24 hours, it is taken out of the aluming, and dried, but without being waſhed. The cotton is then dyed in a weld bath, in the proportion of one pound and a quarter of weld for each pound of cotton, and turned in the bath till it has acquired the proper colour. After being taken out of the bath, it is ſoaked for an hour and a half in a ſolution of blue vitriol (ſulphate of copper), in the proportion of one-fourth of the weight of the cotton, and then immerſed, without waſhing, for nearly an hour, in a boiling ſolution of white ſoap, after which it is well waſhed and dried.

For a deeper yellow

274. A deeper yellow is communicated to cotton, by omitting the proceſs of aluming, and employing two pounds and a half of weld for each pound of cotton. To this is added a dram of verdigriſe, mixed with part of the bath. The cotton is then to be dipped and worked till the colour become uniform. It is then taken out of the bath, that a little ſolution of ſoda may be added, after which it is returned, and kept for fifteen minutes. It is then wrung out and dried.

and other ſhades.

275. Other ſhades of yellow may be obtained, by varying the proportion of ingredients. Thus, a lemon colour is dyed by uſing only one pound of weld for every pound of cotton, and by diminiſhing the proportion of verdigriſe, or uſing alum as a ſubſtitute †.

† Berthollet, ii. 267.

Cheaper and more permanent colours.

276. But a better method, as it affords more permanent and more beautiful colours, and at a ſmaller expence, is recommended by Dr Bancroft. This is by the uſe of quercitron bark, and the calico printers aluminous mordant, or the ſugar of lead. The following is the proceſs which he propoſes to employ, for producing bright and durable yellow colours. One pound of ſugar of lead, and three pounds of alum, are to be diſſolved in a ſufficient quantity of warm water. The cotton or linen, after being properly rinſed, is to be ſoaked in this mixture, heated to the temperature of 100°, for two hours. It is then taken out, moderately preſſed over a veſſel, to prevent the waſte of the aluminous liquor. It is then dried in a ſtove heat, and after being again ſoaked in the aluminous ſolution, it is wrung out and dried a ſecond time. Without being rinſed, it is to be barely wetted with lime water, and afterwards dried, and if a full, bright, and durable yellow is wanted, it may be neceſſary to ſoak the ſtuff in the diluted aluminous mordant, and after drying, to wet it a ſecond time with lime water. After it has been ſoaked for the laſt time, it ſhould be well rinſed in clean water, to ſeparate the looſe particles of the mordant, which might injure the application of the colouring matter. By the uſe of the lime water, a greater proportion of alumina combines with the ſtuff, beſides the addition of a certain portion of lime.

Dyeing bath.

277. In the preparation of the dyeing bath, from 12 to 18 lbs. of powdered quercitron bark are incloſed in a bag, for every 100 lbs. of the ſtuff, varying the proportion according to the intenſity of the ſhade deſired. The bark is put into the water while it is cold; and immediately after the ſtuff is immerſed and agitated or turned for an hour, or an hour and a half, during which the water ſhould be gradually heated, and the temperature raiſed to about 120°. At the end of this time the heat is increaſed, and the dyeing liquor brought to a boiling temperature; but at this temperature the ſtuff muſt remain in it only for a few minutes, becauſe otherwiſe the yellow aſſumes a browniſh ſhade. The ſtuff having thus acquired a ſufficient colour, is taken out, rinſed and dried.

Advantage of a diluted mordant.

278. Dr Bancroft obſerves, that when the aluminous mordant is employed, without the addition of water, one ſoaking only, and an immerſion in lime water, may be ſufficient; but he thinks that greater advantage is derived from the application of a more diluted mordant at two different times, or even by the immerſion of the ſtuff a greater number of times, alternately in the diluted aluminous mordant, and lime water, and drying it after each immerſion. By this treatment he found, that the colour always acquired more body and durability.

Nankeen yellow.

279. Chaptal has propoſed a proceſs for communicating to cotton a nankeen yellow, which at the ſame time that it affords a durable colour, has the advantage of being cheap and ſimple. When cotton is immerſed in a ſolution of any ſalt of iron, it has ſo ſtrong an affinity for the oxide, that it decompoſes the ſalt, combines with the iron, and aſſumes a yellow colour. The proceſs recommended by Chaptal is the following. The cotton to be dyed is put into a cold ſolution of copperas (ſulphate of iron) of the ſpecific gravity 1.02. It is afterwards wrung out, and immediately immerſed in a ley of potaſh of the ſpecific gravity 1.01. This ley muſt have been previouſly ſaturated with a ſolution of alum. When the ſtuff has been kept for four or five hours in this bath, it may be taken out, waſhed and dried. By varying the proportion of ſulphate of iron, every variety of ſhade of nankeen yellow may be obtained.

By another proceſs.

280. We ſhall lay before our readers another proceſs for dyeing nankeen colour, which is propoſed and followed by Mr Brewer, a practical dyer. It is as follows.

" Mix as much ſheep's dung in clear water as will make it appear of the colour of graſs; and diſſolve in clear water one pound of beſt white ſoap for every ten pounds of cotton yarn, or in that proportion for a greater or leſſer quantity.

" Obſerve:—The tubs, boards, and poles, that are uſed in the following preparations muſt be made of deal; the boiling pan of either iron or copper.

Firſt Operation.—" Pour the ſoap liquor prepared as above into the boiling pan; ſtrain the dung liquor through a ſieve; add as much thereof to the ſoap liquor in the pan as will be ſufficient to boil the yarn, intended to be dyed, for five hours. When the liquors are

are well mixed in the pan, enter the yarn, light the fire under the pan, and bring the liquor to boil in about two hours, obſerving to increaſe the heat regularly during that period. Continue it boiling for three hours; then take the yarn out of the pan, waſh it, wring it, and hang it in a ſhed on poles to dry. When dry, take it into a ſtove or other room where there is a fire; let it hang there until it be thoroughly dry.

N. B. "The cotton yarn, when in the ſhed, ſhould not be expoſed either to the rain or ſun: if it is, it will be unequally coloured when dyed.

Second Operation.—"In this operation uſe only one half of the ſoap that was uſed in the laſt, and as much dung liquor (ſtrained as before directed) as will be ſufficient to cover the cotton yarn, when in the pan, about two inches. When theſe liquors are well mixed in the pan, enter the yarn, light the fire, and bring the liquor to boil in about one hour; then take the yarn out, wring it without waſhing, and hang it to dry as in the former operation.

Third Operation.—"This operation the ſame as the ſecond in every reſpect.

Fourth Operation.—"For every ten pounds of yarn make a clear ley from half a pound of pot or pearl-aſhes. Pour the ley into the boiling-pan, and add as much clear water as will be ſufficient to boil the yarn for two hours; then enter the yarn, light the fire, and bring it to boil in about an hour. Continue it boiling about an hour, then take the yarn out, waſh it very well in clear water, wring it, and hang it to dry as in former operations.

N. B. "This operation is to cleanſe the yarn from any oleaginous matter that may remain in it after boiling in the ſoap and dung liquors.

Fifth Operation.—"To every gallon of iron liquor (M) add half a pound of ruddle or red chalk (the laſt the beſt) well pulverized.

"Mix them well together, and let the liquor ſtand four hours, in order that the heavy particles may ſubſide; then pour the clear liquor into the boiling-pan, and bring it to ſuch a degree of heat as a perſon can well bear his hand in it; divide the yarn into ſmall parcels, about five hanks in each; ſoak each parcel or handful very well in the above liquor, wring it, and lay it down on a clean deal board. When all the yarn is handed through the liquor, the laſt handful muſt be taken up and ſoaked in the liquor a ſecond time, and every other handful in ſucceſſion till the whole is gone through; then lay the yarn down in a tub, wherein there muſt be put a ſufficient quantity of ley made from pot or pearl-aſhes, as will cover it about ſix inches. Let it lie in this ſtate about two hours, then hand it over in the ley, wring it, and lay it down on a clear board. If it does not appear ſufficiently deep in colour, this operation muſt be repeated till it has acquired a ſufficient degree of darkneſs of colour: this done, it muſt be hung to dry as in former operations.

N. B. "Any degree of red or yellow hue may be given to the yarn by increaſing or diminiſhing the quantity of ruddle or red chalk.

Sixth Operation.—"For every ten pounds of yarn make a ley from half a pound of pot or pearl-aſhes; pour the clear ley into the boiling-pan: add a ſufficient quantity of water thereto that will cover the yarn about four inches; light the fire, and enter the yarn, when the liquor is a little warm; obſerve to keep it conſtantly under the liquor for two hours; increaſe the heat regularly till it come to a ſcald; then take the yarn out, waſh it, and hang it to dry as in former operations.

Seventh Operation.—"Make a ſour liquor of oil of vitriol and water: the degree of acidity may be a little leſs than the juice of lemons; lay the yarn in it for about an hour, then take it out, waſh it very well and wring it; give it a ſecond waſhing and wringing, and lay it on a board.

N. B. "This operation is to diſſolve the metallic particles, and remove the ferruginous matter that remains on the ſurface of the thread after the fifth operation.

Eighth Operation.—"For every ten pounds of yarn diſſolve one pound of beſt white ſoap in clear water, and add as much water to this liquor in your boiling-pan as will be ſufficient to boil the yarn for two hours. When theſe liquors are well mixed, light the fire, enter the yarn, and bring the liquor to boil in about an hour. Continue it boiling ſlowly an hour; take it out, waſh it in clear water very well, and hang it to dry as in former operations: when dry, it is ready for the weaver.

N. B. "It appears to me, from experiments that I have made, that leſs than four operations in the preparation of the yarn will not be ſufficient to cleanſe the pores of the fibres of the cotton, and render the colour permanent *."

Proceſs followed in the eaſt.

281. A method of dyeing cotton and linen a durable yellow colour is practiſed in the eaſt. The object of this proceſs, which is tedious, is to increaſe the affinity between the alumina and the ſtuff, ſo that it may adhere with ſufficient force to produce a permanent colour. For this purpoſe three mordants are employed: theſe are oil, tan and alum. The cotton is ſoaked in a bath of oil, mixed with a weak ſolution of ſoda. Animal oil, as it is found to anſwer beſt, is preferred. Glue has alſo been tried, and is found to anſwer very well. The ſoda muſt be in the cauſtic ſtate, for in that ſtate it combines with the oil, and produces on the cloth an equal abſorption. The ſtuff is then to be waſhed, and afterwards put into an infuſion of nut galls of the white kind, and the infuſion ſhould be uſed hot. The tan combines with the oil, while the gallic acid carries off any portion of alkali which may adhere to the cloth. When the ſtuff is removed from the bath, it ſhould be quickly dried; and too great an exceſs of galls beyond a proper proportion with the oil ſhould be avoided, as it is apt to darken the ſhade of colour. After this preparation the ſtuff is to be immerſed in a ſolution of alum; and in conſequence of the affinity which exiſts between tan and alumina, the alum is decompoſed, and its earth combines with the tan. After theſe preliminary ſteps, the cotton is to be dyed with quercitron bark, according to the proceſs which has been already deſcribed.

SECT. III.

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* Edin. Mag. xxii.

(M) Iron liquor is what the linen printers uſe.

Sect. III. *Of Blue.*

282. The next of the ſimple colours is blue. We ſhall firſt treat of the ſubſtances which are employed in dyeing blue, and then deſcribe the proceſſes which are followed in fixing this colour.

I. *Of the Subſtances which are employed in Dyeing Blue.*

The only ſubſtances which are uſed in dyeing blue, are indigo and woad.

Indigo

283. Indigo was not uſed for the purpoſe of dyeing in Europe till near the middle of the 16th century. A ſubſtance is mentioned by Pliny *, which was brought from India, and termed *indicum*, which ſeems to have been the ſame as the indigo of the moderns; but it does not appear that either the Greeks or the Romans knew how to diſſolve indigo, or its uſe in dyeing, although it was applied as a paint. It was, however, long before known as a dye in India. The firſt indigo which was employed for the purpoſe of dyeing by Europeans, was brought by the Dutch from India. One of the ſpecies of the plant from which it is obtained, was diſcovered by the Portugueſe in Brazil, where it grows ſpontaneouſly, as well as in other parts of America. Being afterwards ſucceſsfully cultivated in Mexico, and ſome iſlands of the Weſt Indies, the whole of the indigo employed in Europe was ſupplied from theſe countries. The indigo from the Eaſt Indies has, however, of late recovered its character, and is imported into Britain in conſiderable quantities.

introduced into Europe.

Three ſpecies.

284. There are three ſpecies of the indigo plant, which are uſually cultivated in America. The firſt is the *indigofera tinctoria*, Linn. which beſides being a ſmaller and leſs hardy plant, is inferior to the others on account of its pulp, but as it yields a greater proportion, it is generally preferred. The ſecond is the *indigofera diſperma*, Linn. or *Guatimala indigo plant*. This is a taller and hardier plant, and affords a pulp of a ſuperior quality to the former. The third is the *indigofera argentea*, Linn. which is the hardieſt of the three ſpecies; yields a pulp of the fineſt quality, though in ſmalleſt proportion.

Method of preparing indigo.

285. When the indigo plant has arrived at maturity, it is cut a few inches above the ground, diſpoſed in ſtrata in a large veſſel or ſteeper, and being kept down with boards, is covered with water; and in this ſtate it is left to ferment till the pulp is extracted. The proceſs commences by the evolution of heat, and the emiſſion of a great quantity of carbonic acid gas. When the fermentation has continued for a ſufficient length of time, which is known by the tops becoming tender and pale, the liquor, which is now of a green colour, is drawn off into large flat veſſels, called *beaters*, where it is agitated with buckets or other convenient apparatus, till blue flocculæ begin to appear. To promote this granulation or ſeparation of the flocculæ it is uſual to add clear lime water till the liquor in which they are ſuſpended become quite colourleſs. The liquor being ſufficiently impregnated with the lime water, is left at reſt to allow the particles of the colouring matter to precipitate; after which the ſupernatant liquor is drawn off, and the ſediment collected into linen bags, which are ſuſpended for ſome time to let the water drain off. It is then put into ſquare boxes, or formed into lumps and dried in the ſhade. The indigo thus prepared is in a ſtate fit for the market.

Varies in its qualities.

286. The indigo which is produced in this operation differs greatly, not only according to the quality of the plant from which it is obtained, but according to the mode of preparation. But the difference of quantity ſeems to depend entirely on the heterogeneous ſubſtances with which it is mixed, and on the degree of conſiſtence which it has acquired in drying. The lighteſt kind which, is brought from Guatimala, is called *light indigo;* it is of a fine blue colour, and is the moſt valuable, becauſe it is of the fineſt quality. Indigo exhibits various ſhades of colour, which is alſo owing to the mixture of foreign ſubſtances. The moſt common ſhades are blue, violet, and copper colour.

Is obtained from other plants.

287. Other plants have alſo been diſcovered, which by a proceſs ſomewhat ſimilar, afford indigo, and in particular the *nerium tinctorium*, or roſe bay, an account of which, with the method of manufacturing indigo from its leaves, has been given by Dr Roxburgh. This tree grows in great abundance in different parts of the Eaſt Indies; and plantations of it, raiſed from ſeeds, have ſucceeded well in Bengal. The leaves of the nerium afford indigo, not only when they are freſh gathered, but alſo when they are nearly dried; but they yield the beſt indigo after being kept a day or two. The leaves collected the preceding day are put into a copper, ſo as nearly to fill it without preſſing. The copper is filled with water till within three inches of the top; and hard ſpring water, which increaſes the quantity of indigo, and improves its quality, is preferred. The fire is then applied, and kept up, till the liquid becomes of a green colour in the veſſel. The leaves then become of a yellowiſh colour, and the heat of the liquor about 150°, or 160°. The leaves ſhould be conſtantly agitated, that they may be equally heated, as well as to promote the operation, by the expulſion of the carbonic acid gas. When the proceſs exhibits the above appearances, the liquor is to be drawn off, paſſed through a hair-cloth, and agitated while hot in the uſual way, till granulation takes place, or the appearance of blue flakes is obſerved. About $\frac{1}{75}$ part of ſtrong lime water is then added, to promote the precipitation of the indigo, and the remaining part of the proceſs is ſimilar to that deſcribed above, for the manufacture of indigo from *indigofera* †.

Nature of the ſubſtances extracted.

288. The object of the proceſſes which are followed in the manufacture of indigo, is to extract from the plants which yield it, a green ſubſtance, which is ſoluble in water. This ſubſtance, which has a ſtrong affinity for oxygen, gradually attracts it from the air, becomes of a blue colour, and is then inſoluble in water. This abſorption is greatly promoted by agitation, for then a greater ſurface is expoſed to the action of the air; and the lime water, by combining with carbonic acid, which exiſts in the green matter, alſo promotes the ſeparation of the indigo.

Properties of indigo.

289. Indigo is inſoluble in water, alcohol, ether, and oils, and the only acids which produce any effect upon it, are the ſulphuric and nitric. By the latter it is ſoon changed to a dirty white colour, and is at laſt entirely decompoſed. When the acid is concentrated, the indigo is inflamed; but when it is diluted, the indigo becomes brown, and cryſtals like thoſe of oxalic and

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* *Lib.* xxxv.

† *Bancroft*, 427.

and tartarous acids make their appearance; and when the acid and cryſtals are waſhed off, there remains behind a kind of reſinous matter. Sulphuric acid in the concentrated ſtate diſſolves indigo, with the evolution of a great deal of heat. The ſolution is opaque and black, but when diluted with water, it changes to a deep blue colour. Dr Bancroft has denominated this ſolution *ſulphate of indigo*, which has been long known by the name of *liquid blue*. The fixed alkalies in the ſtate of carbonate precipitate ſlowly from ſulphate of indigo, a blue coloured powder, which has the properties of indigo, but is found to be ſoluble in moſt of the acids and alkalies. Pure alkalies deſtroy the colour of ſulphate of indigo, as well as that which is precipitated.

Is employed in dyeing in two ſtates.

290. Indigo is employed in dyeing, both in the ſtate of liquid blue, or ſulphate of indigo, from which is obtained the beautiful colour called *Saxon blue*; and alſo in the ſtate of ſimple indigo, or the indigo of commerce. In dyeing with indigo, it muſt be reduced to the ſtate of the green matter as it exiſts in the plants, or when it is firſt extracted from them. It muſt be deprived of the oxygen, to the combination of which the blue colour is owing. In this ſtate it becomes ſoluble in water by means of the alkalies. To effect this ſeparation of the oxygen, the indigo muſt be mixed with a ſolution of ſome ſubſtance which has a ſtronger affinity for oxygen than the green matter of indigo. Such ſubſtances are green oxide of iron and metallic ſulphurets. Lime, green ſulphate of iron, and indigo, are mixed together in water, and during this mixture the indigo is deprived of its blue colour, becomes green, and is diſſolved, while the green oxide of iron is converted into the red oxide. In this proceſs, part of the lime decompoſes the ſulphate of iron, and as the green oxide is ſet at liberty, it attracts oxygen from the indigo, and reduces it to the ſtate of green matter, which is immediately diſſolved by the action of the reſt of the lime. Indigo is alſo deprived of its oxygen, and prepared for dyeing, by another proceſs. Some vegetable matter is added to the indigo mixed with water, with the view of exciting fermentation; and quicklime or an alkali is added to the ſolution, that the indigo, as it is converted into the green matter, may be diſſolved.

Woad.

291. Another plant, known under the name of *paſtel* or *woad*, (*iſatis tinctoria*), is employed for dyeing blue. Another ſpecies (*iſatis luſitanica*), which is a ſmaller plant, is alſo employed in dyeing. The *iſatis tinctoria* is cultivated in France and in England. When the plant has reached maturity, it is cut down, waſhed in a river, and ſpeedily dried in the ſun. It is then ground in a mill, and reduced to a paſte, which is formed into heaps, covered up to protect them from the rain, and at the end of a fortnight the heap is opened, to mix the whole well together. It is afterwards formed into round balls, which are expoſed to the wind and ſun, that the moiſture may be ſeparated. The balls are heaped upon one another, become gradually hot, and exhale the ſmell of ammonia. To promote the fermentation, which is ſtronger in proportion to the quantity heaped up, and the temperature of the ſeaſon, the heap is to be ſprinkled with water till it falls down in the ſtate of coarſe powder, in which ſtate it appears in commerce. The blue colour obtained from woad is very permanent, but has little luſtre. But its colour is not only inferior in beauty to that obtained from indigo; it affords alſo a ſmaller proportion of colouring matter, ſo that ſince the diſcovery of indigo, the uſe of woad has diminiſhed.

II. *Of the Proceſſes for Dyeing Wool Blue.*

Preparation of the vat.

292. The preparation for dyeing blue is made in a large wooden veſſel or vat, which ſhould be ſo conſtructed as to retain the heat, which is a matter of conſiderable importance in the proceſs. The vat is therefore ſet up in a ſeparate place from the coppers, and is ſunk ſo far in the ground as to be only breaſt-high above it. Before the introduction of indigo, blue was dyed with woad, which affords a permanent, but not a deep colour; but a very rich blue is obtained by mixing indigo with the woad, and theſe are almoſt the only ſubſtances which are now employed for dyeing woollen ſtuffs. The proportions of theſe ſubſtances are varied by different dyers, and according to the ſhade which is required. The following is the account of the preparation of a vat, as it is given by Quatremere. Into a vat of about ſeven and a half feet deep, and five and a half in diameter, are thrown two balls of paſtel or woad, which are previouſly broken, and together amount to about 400 pounds weight; 30 pounds of weld are boiled in a copper for three hours, in a ſufficient quantity of water, to fill the vat. To this decoction are added 20 pounds of madder, and a baſket full of bran. The boiling is then continued half an hour longer. This bath is cooled with 20 buckets of water, and after it is ſettled, and the weld taken out, it is poured into the vat, which muſt be ſtirred with a rake all the time that it is running in, and for 15 minutes longer. The vat is then covered up very hot, and allowed to ſtand for ſix hours, when it is uncovered, and raked again for 30 minutes. The ſame operation muſt be repeated every three hours. When the appearance of blue ſtreaks is perceived on the ſurface of the vat, eight or nine pounds of quicklime are added; the colour then becomes of a deeper blue, and the vat exhales more pungent vapours. Immediately after the lime, or along with it, the indigo, which has been previouſly ground in a mill, with the ſmalleſt poſſible quantity of water, is put into the vat. The quantity is to be regulated by the intenſity of the ſhade required. From ten to thirty pounds may be put into a vat ſuch as we have now deſcribed. If on ſtriking the vat with the rake, a fine blue ſcum ariſes, no other previous preparation is required than to ſtir it with the rake twice in the ſpace of ſix hours, to mix the ingredients completely. Great care ſhould be taken not to expoſe the vat to the air, except during the time of ſtirring it. When that operation is finiſhed, it is covered with a wooden lid, on which are ſpread thick cloths, to retain the heat as much as poſſible; but after all theſe precautions, at the end of eight or ten days it is greatly diminiſhed, and is at laſt entirely diſſipated, ſo that the liquor muſt be again heated, by pouring the greater part of the liquor of the vat into a copper under which a large fire is made. When the liquor has acquired a ſufficient temperature, it is returned into the vat, and carefully covered up.

Accidents to which the vat is liable.

293. Vats of this deſcription are ſometimes liable to accidents. A vat is ſaid to be repelled, when having previouſly afforded fine ſhades of blue, it appears black,

black, without any blue ſtreaks; and if it be ſtirred, the black colour becomes deeper; the vat at the ſame time exhales, inſtead of a ſweetiſh ſmell, a pungent odour; and the ſtuff dyed in a vat in this ſtate, comes out of a dirty gray colour. Theſe effects are aſcribed to an exceſs of lime.

Means of obviating them,

294. Different means are employed to recover a repelled vat. Some are ſatisfied with merely reheating it; while others add tartar, bran, urine, or madder. Hellot recommends bran and madder as the beſt remedy. If the exceſs of lime be not very great, it is ſufficient to leave it at reſt five or ſix hours, putting in a quantity of bran and three or four pounds of madder, which are to be ſprinkled on the ſurface, and then it is to be covered up, and after a certain interval, to be tried again. But if the vat has been ſo far repelled as to afford a blue only when it is cold, it muſt be left at reſt to recover, and ſometimes muſt remain whole days without being ſtirred with the rake. When it begins to afford a tolerable pattern, the bath muſt be reheated. In general, this revives the fermentation. The addition of bran or madder, or a baſket or two of freſh woad, produces the ſame effect.

and remedying putrefaction.

295. This vat ſometimes runs into the putrefactive proceſs. When this happens, the colour of the vat becomes reddiſh, the paſte riſes from the bottom, and a fetid ſmell is exhaled. This accident is owing to a deficiency of lime, and it muſt be corrected by adding a freſh quantity. The vat is then to be raked; after two hours more lime is added, and the proceſs of raking again performed. Theſe operations are to be repeated till the vat is recovered.

Precautions in the uſe of lime.

296. Nothing requires more attention in treating a vat of this kind, than the diſtribution of the lime, the principal uſe of which is to moderate the tendency to putrefaction, and to limit the fermentation to that degree which is neceſſary to deprive the indigo of its oxygen. If too much lime be added, the neceſſary fermentation is retarded, and if there be too little, the putrefactive proceſs commences.

Dyeing proceſs.

297. Two hours previous to the dyeing operation, the vat ſhould be raked; and to prevent the ſtuff coming in contact with the ſediment, which would produce inequalities in the colour, a croſs of wood is introduced. The ſtuff is then to be completely wetted with pure water a little heated; and being wrung out, it is dipped into the vat, where it is moved about for a longer or a ſhorter time, according to the depth of ſhade required. During this operation it is taken out occaſionally, to be expoſed to the air, the action of which is neceſſary to change the green colour of the bath into a blue. Stuffs dyed blue in this manner muſt be carefully waſhed, to carry off the looſe particles of colouring matter; and when the ſhade of blue is deep, they ought even to be cleanſed, by fulling with ſoap. This operation does not alter the colour.

Indigo vat.

298. When a vat is prepared entirely of indigo, without paſtel or woad, it is called an *indigo vat*. The veſſel employed for this purpoſe is of copper, into which water is poured according to its capacity, to the amount of 40 buckets, in which have been boiled ſix pounds of potaſh, twelve ounces of madder, and ſix pounds of bran. Six pounds of indigo ground in water are then put in, and after it has been carefully raked, the vat is to be covered. A ſlow fire is to be kept up, and twelve hours after it is filled, it is to be raked a ſecond time. This operation is to be repeated every twelve hours, till it come to a blue colour, which will generally be the caſe in about 48 hours. If the bath is properly managed, it will be of a fine green, exhibiting on the ſurface coppery ſcales, and a blue ſcum or flower. In this vat the indigo is rendered ſoluble in water, by means of the alkali inſtead of lime. The dyeing operation is to be conducted in the ſame manner as the preceding.

Hellot's vats.

299. Two vats have been deſcribed by Hellot, in which the indigo is diſſolved by means of urine. Madder is added to it, and in the one vinegar, in the other alum and tartar, of each a quantity equal in weight to that of the indigo. The proportion of urine muſt be conſiderable. In conſidering the theory of this proceſs, it ſeems probable that the indigo, deprived of its oxygen by the urine and madder during the fermentation, is diſſolved by the ammonia which is formed in the urine. When the ſolution of alum and tartar is added, an effervеſcence, which Hellot obſerved, is produced. This, it is probable, has a tendency to retard or ſtop the putrefaction. But in vats of this deſcription, operations on a large ſcale cannot be carried on; they ſeem only adapted for ſmall dye-houſes.

III. *Of the Proceſſes for Dyeing Silk Blue.*

With indigo.

300. Silk is dyed blue with indigo alone, without any proportion of woad. The proportion of indigo mentioned in the preparation of the indigo vat, and ſometimes a larger proportion, is employed, with ſix pounds of bran, and about twelve ounces of madder. According to Macquer, half a pound of madder for each pound of potaſh, renders the vat greener, and produces a more fixed colour in the ſilk. When the vat is come to, it ſhould be refreſhed with two pounds of potaſh, and three or four ounces of madder; and after being raked in the courſe of four hours, it is fit for dyeing. The temperature ſhould be ſo moderated, that the hand may be held in it without uneaſineſs.

Preparation of the ſilk.

301. The ſilk, after being boiled with ſoap, in the proportion of 30 pounds of ſoap to 100 of ſilk, and well cleaned by repeated beetlings in a ſtream of water, muſt be dyed in ſmall portions, becauſe it is apt to take on an uneven colour. When it has been turned once or oftener in the bath, it is wrung out, and expoſed to the air, that the green colour may change to a blue. When the change is complete, it is thrown into clear water, and afterwards wrung out. Silk dyed blue ſhould be ſpeedily dried. In damp weather and in winter, it is neceſſary to conduct the drying in a chamber heated by a ſtove. The ſilk ſhould be hung on a frame kept conſtantly in motion. To dye light ſhades, ſome dyers employ vats that are ſomewhat exhauſted; but it ought to be obſerved, that the colour thus obtained is leſs beautiful and leſs permanent than when freſh vats, containing a ſmaller quantity of indigo, are employed.

For Turkey blue.

302. Some addition is required to be made to the indigo, to give ſilk a deep blue. A previous preparation is neceſſary, by giving it another colour or ground. For the Turkey blue, which is the deepeſt, a ſtrong bath of archil is firſt prepared. Cochineal is alſo ſometimes uſed, inſtead of archil, for the ground, to render the colour more permanent. A blue is given to ſilk

ſilk by means of verdigriſe and logwood, but it poſſeſſes little durability. It might be rendered more permanent, by giving it a lighter ſhade in this bath, then dipping it in a bath of archil, and finally in the indigo vat.

Dyeing raw ſilk.

303. When raw ſilk is to be dyed blue, ſuch as is naturally white ſhould be ſelected. Being previouſly ſoaked in water, it is put into the bath in ſeparate hanks, as already directed for ſcoured ſilks; and as raw ſilk is found to combine more readily with the colouring matter, the ſcoured ſilk, when it can be conveniently done, ſhould be firſt put into the bath. If archil, or any of the other ingredients which have been already mentioned, are required, to give more intenſity to the colour, the mode of application is the ſame as that directed for ſcoured ſilk.

IV. *Of the Proceſſes for Dyeing Cotton and Linen Blue.*

Preparation of the vat.

304. For dyeing cotton and linen blue, Pileur d'Apligny recommends a vat containing about 120 gallons. From ſix to eight pounds of indigo reduced to powder, are boiled in a ley drawn off from a quantity of lime, equal in weight to the indigo, and a quantity of potaſh double its weight. During the boiling, which is to be continued till the indigo is completely penetrated with the ley, the ſolution muſt be conſtantly ſtirred, to prevent the indigo from being injured, by adhering to the bottom of the veſſel.

305. During this proceſs, another quantity of quicklime, equal in weight to the indigo, is to be ſlaked. Twenty quarts of warm water are added, in which is to be diſſolved a quantity of copperas (ſulphate of iron) equal to twice the weight of the lime. The ſolution being completed, it is poured into the vat, which is previouſly half filled with water. To this the ſolution of indigo is added, with that part of the ley which was not employed in the boiling. The vat muſt now be filled up to within two or three inches of the top. It muſt be raked twice or thrice a day till it is completely prepared, which is generally the caſe in 48 hours, and ſometimes ſooner, as it depends on the temperature of the atmoſphere. A ſmall proportion of bran, madder, and woad, is recommended by ſome, to be added to ſuch a vat as we have now deſcribed.

A ſimpler proceſs.

306. The proceſs which is followed at Rouen, and deſcribed by Quatremere, is ſimpler. The vats, which are conſtructed of a kind of flint, are coated within and without with fine cement, and are arranged in one or more parallel lines. Each vat contains four hogſheads of water. The indigo, to the amount of 18 or 20 pounds, being macerated for a week in a cauſtic ley, ſtrong enough to bear an egg, is ground in a mill; three hogſheads and a half of water are put into the vat, and afterwards 20 pounds of lime. The lime being thoroughly ſlaked, the vat is raked, and 36 pounds of copperas are added; and when the ſolution is complete, the ground indigo is poured in through a ſieve. It is raked ſeven or eight times the ſame day, and after being left at reſt for 36 hours, it is in a ſtate fit for dyeing.

Proceſs on a larger ſcale.

307. In extenſive manufactories, it is neceſſary to have vats ſet at different times. In conducting the proceſs of dyeing, the ſtuffs are firſt dipped in the moſt exhauſted vat, and then regularly proceeding from the weakeſt to the ſtrongeſt, if they have not previouſly attained the deſired ſhade. The ſtuffs ſhould remain in the bath only about five or ſix minutes, for in that time they combine with all the colouring matter they can take up. After the ſtuffs have been dipped in a vat, it ſhould not be uſed again, till it has been raked, and ſtood at leaſt 24 hours, unleſs it has been lately ſet, when a ſhorter period is ſufficient.

308. After the ſtuffs have been dipped three or four times in a vat, it begins to change. It becomes black, and no blue or copper-coloured ſtreaks are ſeen on the ſurface after raking it. It muſt then be renewed, by adding four libs. of copperas, with two of quicklime, after which it muſt be raked twice. In this way a vat may be renewed three or four times; but the additional quantity of ingredients muſt be diminiſhed, as the ſtrength of the vat is exhauſted *.

Proceſs of Bergman.

309. A vat which is ſtill more ſimple, and more eaſily prepared, has been recommended by Bergman. The proportion of the ingredients which he has directed to be employed, is the following. To three drachms of indigo reduced to powder, three drachms of copperas, and three of lime, add two pints of water. Let it be well raked, and in the courſe of a few hours it will be in a proper ſtate for dyeing.

Hauſſman's.

310. Hauſſman employs ſtill a ſmaller proportion of indigo. For 3000 libs. of water he takes 36 libs. of quicklime ſlaked in 200 libs. of water, with which the indigo in the proportion of from 10 to 20 libs. well ground, is to be mixed. He then diſſolves 30 libs. of copperas in 120 libs. of hot water. The whole being left at reſt for fifteen minutes, the vat is filled, and gently and conſtantly ſtirred. When a deeper ſhade is wanted, and particularly when linen is to be dyed, the proportion of indigo ſhould be greater; but the ſhade depends very much on the time the ſtuffs remain in the vat, and the times it has been uſed. When the vat becomes turbid, the proceſs of dyeing muſt be interrupted, till it has been again raked, and the ſupernatant liquor become tranſparent. If the effects of the lime fail, a new quantity freſh ſlaked, muſt be added; and if the iron ceaſe to produce the effect on the indigo, a new portion muſt be alſo added, obſerving the precaution to have a greater quantity of lime than what is neceſſary to ſaturate the ſulphuric acid. When the indigo ſeems to be exhauſted, freſh portions ground in water are alſo to be added; the vat is to be raked ſeveral times, and allowed to ſettle, after which it is again fit for uſe. In this way Mr Hauſſman informs us he preſerved a vat for the ſpace of two years; and had it not been for the accumulation of ſediment, which prevented the ſtuffs from being immerſed to a ſufficient depth, it might have been continued in uſe for a much longer time. It is worth while to add, that Mr Hauſſman found, that a pattern of cloth dipped in water, acidulated with ſulphuric acid, immediately after it was taken out of the bath, became of a much deeper blue than a ſimilar pattern expoſed to the air, or another dipped in river water.

311. Another convenient and expeditious vat is mentioned by Bergman, and deſcribed by Scheffer. Indigo reduced to fine powder, in the proportion of three drachms to a quart, is added to the ſtrong ley of the ſoap-boiler. After a few minutes, when the colouring matter is well penetrated by the ley, ſix drachms of powdered orpiment are to be added. In a few minutes after the bath has been well raked, it becomes green, and

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* *Berthollet*, ii. 90.

and the blue ſtreaks appear on the ſurface. Heat is to be applied; when the operation of dyeing may commence.

312. The preparation employed for printing cottons is ſimilar to the above bath, excepting in the proportions of orpiment and indigo, which are greater in the former; but theſe proportions are very different in different manufactories.

Diſcovery of Saxon blue.

313. *Saxon Blue.*—The colour which is obtained by dyeing with a ſolution of indigo in ſulphuric acid is known under the name of *Saxon blue*, becauſe the proceſs was firſt carried on at Groſſenhayn in Saxony, by Counſellor Barth, who made the diſcovery about the year 1740. This diſcovery was for ſome time kept ſecret, and the method ſeems to have been originally very complicated. Alumina, antimony, and ſome other ſubſtances, were previouſly added to the ſulphuric acid. Theſe, however, are now omitted, and the indigo alone is diſſolved in the acid.

Preparation of the dye.

314. From a great number of experiments which were made on this proceſs by Bergman, he concluded, that in thoſe caſes where the ſulphate of indigo afforded only a fading colour, the acid employed had been too weak. Quatremere obſerves that, among ſeveral proceſſes for dyeing with ſulphate of indigo, he diſcovered only two, in which the ſtuffs were completely penetrated with colouring matter. To effect this, he employed an alkali, in the proportion of one ounce to an ounce of indigo, and ſix ounces of ſulphuric acid. With theſe proportions of the ingredients he obtained a deep vivid blue, equally intenſe through every part of the ſtuff. Poerner, who has paid great attention to this preparation, alſo employs an alkali, by means of which a more pleaſing colour, which penetrates deeper, is produced. The proportions which he recommends are four parts of ſulphuric acid to one of indigo. The indigo is firſt reduced to a fine powder, and the ſulphuric acid, in the concentrated ſtate, is poured upon it. The mixture is ſtirred for ſome time, and having ſtood twenty-four hours, one part of dry potaſh in fine powder, is added; and after the whole is again ſtirred, it remains for twenty-four hours longer. It is then to be diluted with eight times its weight of water, which muſt be gradually added, or a greater or leſs proportion as may be wanted.

By Bancroft.

Dr Bancroft ſeems to be of opinion, that a more durable blue may be obtained by diluting the acid with an equal quantity of water, when the indigo is put in, and allowing the mixture to remain forty-eight hours; for he thinks by this ſlower and more moderate action, the baſis of the indigo is leſs injured. Inſtead of the potaſh employed by Poerner, Dr Bancroft uſes chalk; and even in ſuch a quantity as to ſaturate the acid. In this caſe the indigo is precipitated along with the chalk; and, when collected into a ſolid maſs, communicates a blue colour to wool, but more ſlowly than by the common method, in which the combination is very rapid and the dyeing unequal. This inconvenience he thinks might be obviated by the uſe of chalk *.

For woollen ſtuffs.

315. To produce a Saxon blue colour on woollen ſtuffs, they are prepared with alum and tartar. And in proportion to the ſhade required, the quantity of ſolution of indigo put into the bath muſt be regulated. When a deep ſhade of Saxon blue is wanted, the ſtuff muſt be paſſed different times through veſſels containing ſuch a quantity of colouring matter as is ſufficient to give light colours. In this way, by repeated applications, the colour becomes more uniform.

For ſilk.

316. The ſulphate of indigo is alſo employed to dye ſilk. For this purpoſe attempts have been made to unite the advantages of the indigo vat and its ſolution in ſulphuric acid. A proceſs of this kind is greatly recommended by Guhliche, which produces beautiful colours, and is at the ſame time cheap and convenient. The bath is compoſed of one pound of indigo, three pounds of quicklime, three of copperas, and one and a half of orpiment. The indigo is firſt to be carefully ground and mixed with water, put into a wooden vat, and diluted with water, according to the ſhade of colour wanted. The lime is then to be added, and the mixture being well ſtirred, it is covered up, and allowed to remain at reſt for ſome hours. After this the copperas in the ſtate of powder is added, the whole well ſtirred, and the vat covered up. And laſtly, at the end of ſome hours, the orpiment reduced to powder is thrown in, and the whole left at reſt for ſeveral hours. The mixture is afterwards to be ſtirred, and then left to ſettle, till the liquor becomes clear; when the blue ſtreaks or flower which covers it is removed, and the ſilk previouſly dipped in warm water, is to be dyed hank by hank. When it is removed from the bath, it is to be waſhed in a ſtream of water, and dried.

317. This proceſs is recommended as the means of obviating a greeniſh caſt, which is ſometimes obſerved in Saxon blue, and which is ſuppoſed to be owing to ſome change in the particles of indigo, by means of the ſulphuric acid.

Engliſh blue.

318. The colour denominated *Engliſh blue* is produced by means of the ſulphate of indigo. To give ſilk this colour, it is firſt to be dyed a light blue; and, when taken out of this bath, it is dipped in hot water, waſhed in a ſtream, and left in a bath compoſed of the ſulphate of indigo, to which a little of the ſolution of tin has been added, until the proper ſhade is obtained, or the bath is exhauſted. Previous to its being put into this bath, it may be dipped in a ſolution of alum, in which it ſhould only remain a very ſhort time. Silk, which has been dyed according to this proceſs, is free from the reddiſh ſhade which it derives from the blue vat, as well as from the greeniſh caſt of the Saxon blue *.

319. The ſulphate of indigo has been hitherto only applied for the purpoſe of dyeing wool and ſilk. The affinity of indigo for vegetable ſubſtances is not ſufficiently ſtrong to effect the decompoſition of the ſulphate. It cannot, therefore, be employed with advantage in dyeing cotton and linen.

Dyeing with pruſſian blue.

320. Attempts have been made to dye with Pruſſian blue. The proceſs which was followed by Macquer is the following. He ſoaked wool, ſilk, cotton, and thread, in a ſolution of alum and ſulphate of iron, and afterwards in an alkaline ſolution, which was partly ſaturated with pruſſic acid. He then immerſed the ſtuffs in water, acidulated with ſulphuric acid, for the purpoſe of diſſolving that part of the oxide of iron which remained uncombined with the pruſſic acid, and which the uncombined alkali had precipitated. By ſucceſſive repetitions of theſe immerſions he obtained a fine blue, but very unequal. Berthollet juſtly remarks on this experiment,

* *Phil of Perm. Col.* 132.

* *Berthollet*, ii. 319.

experiment, that an alkali ſaturated with pruſſic acid ſhould be employed, or lime water or magneſia, both of which have the property of combining with that acid. In a ſecond experiment Macquer boiled the ſtuffs in a ſolution of tartar and alum, and then paſſed them through a bath which contained the pruſſian blue merely diffuſed in it. The colour was faint, and could not be made deeper; but it was equal, and ſoft to the touch.

Another proceſs.

321. In the proceſs propoſed by Abbé Menon for thread and cotton, they are firſt dyed black, and ſoaked for a few minutes in pruſſiate of alkali, and afterwards boiled in a ſolution of alum. In this way they acquired a deep blue. When a lighter blue is wanted, the ſtuffs muſt be paſſed through a weak acid.

De la Platiere's.

322. Similar to the ſecond experiment of Macquer is the proceſs of Roland de la Platiere. He takes pruſſian blue in the proportion of a pound to a piece of ſtuff, powdered, and paſſed through a very fine ſieve, and adds muriatic acid till it is reduced to the conſiſtence of ſyrup. It is to be conſtantly ſtirred for about half an hour, while it ferments. It is then well diluted, and ſtirred every hour for a day, till the fermentation ceaſes. The particles are thus in a ſtate of minute diviſion. Seven or eight buckets of water for one piece of velvet, are put into a trough; then add the mixture, which has been previouſly well diluted in a ſeparate veſſel, and poured into the bath through a very fine ſieve. When the piece is placed on the winch, over the trough, let the bath be briſkly ſtirred, and the piece ſpeedily let down; and the ſame operation muſt be continued as quickly as poſſible for ſeveral hours. This colour requires great management, for as the particles of the pruſſian blue are only in a ſtate of minute diviſion, and heavy, they are quickly depoſited on the ſtuff. Hence the colour appears very unequal and in patches, even with the utmoſt care; and nothing can be done to avoid it, but repeating the operations again and again. The ſtuff ſhould be put into the baths thoroughly wet, for when it is dry, it penetrates with difficulty, and is always unequal. Between the dryings the ſtuff is always to be waſhed and beetled, excepting the laſt time, when it is not waſhed, but dried in the open air, either in the ſun or in the ſhade; obſerving however, that it be well ſtretched. This beautiful colour is not changed by the air; it reſiſts the action of acids, and is little altered by boiling with alum; but it is ſoon tarniſhed by friction, or particles of duſt that adhere to it. It is ſcarcely neceſſary to add, that it is inſtantly decompoſed by alkaline liquors. Guhliche employs a ſolution of tin in nitro-muriatic acid, as a ſubſtitute for muriatic acid, in the proceſs of dyeing with pruſſian blue *.

Bancroft's.

323. Dr Bancroft made a number of experiments in dyeing both vegetable and mineral matters, with pruſſian blue, and particularly with the view of obviating the difficulties which had occurred to others in the uſe of it. He boiled up copperas with quercitron bark, fuſtic, and logwood, ſeparately, in what he thought the beſt proportions; and in each of theſe mixtures he dyed a piece of woollen cloth by boiling it for 10 or 15 minutes. The ſtuffs were afterwards ſeparately immerſed in warm diluted pruſſiate of potaſh neutralized by ſulphuric acid. They acquired an equal and beautiful blue. This however, was not the uniform reſult; for when too much copper as was employed in dyeing with quercitron bark, there was an exceſs of oxide of iron, which combining with the fibres of the wool, gave the pruſſian blue a greeniſh tinge; but this he found could be remedied, by paſſing the cloth through warm water, ſlightly acidulated with muriatic acid. The pruſſian colouring matter, Dr Bancroft obſerves, muſt always be applied in a moderate heat, otherwiſe it will be precipitated by the ſulphuric acid, and rendered unfit for this purpoſe, till it is again diſſolved by potaſh, lime, or ſome other ſubſtance.

324. He then tried to fix pruſſian blue by means of the aluminous mordant, but at the end of 15 minutes, after being immerſed in a ſolution of pruſſiate of potaſh, it had acquired no colour. The addition of a ſmall proportion of a ſolution of iron in muriatic acid, communicated a blue colour. All parts of the cloth, as well as thoſe to which the mordant had been applied, received the colour. The cloth being waſhed with ſoap, the whole of the colour was diſcharged, excepting where it had been impregnated with alumina, and even there it had become fainter. A piece of the ſame cotton was immerſed in a ſolution of ammonia (volatile alkali); the pale blue was greatly heightened. Another piece was put into water ſlightly tinctured with a ſolution of copper in ammonia. The blue colour became ſuddenly of an intenſely deep garter-blue or violet, and it reſiſted the action of ſoap. Into water mixed with a little of a ſolution of muriate of copper, he put another piece of the ſame cotton, and it ſoon became of a deeper blue, without any of the purple or violet ſhade. This reſiſted the action of ſoap, and after long expoſure to the weather, the colour was little diminiſhed; and when the colour remained in any degree weakened, immerſion in water ſlightly acidulated with ſulphuric acid, completely reſtored it. From theſe facts it would appear to be advantageous to prepare woollens by the uſual boiling with alum, or alum and tartar, before they are dyed with copperas and quercitron bark, fuſtic or logwood, for a pruſſian blue; but a greater proportion of ſulphuric acid, in the pruſſiate of potaſh or lime, that the exceſs of acid may diſcharge the vegetable colouring matters becomes neceſſary *.

For ſilk and cotton.

325. Dr Bancroft afterwards tried pieces of ſilk and cotton in the diluted pruſſiates of potaſh, ſoda, lime, &c. with ſolutions of moſt of the metals in different acids and alkalies; and from the different metallic ſolutions he obtained a very full, lively colour, which he calls the *red copper colour*; from the different ſolutions of copper in ſulphuric, nitric, muriatic, and acetic acids; the ſame effect ſucceeded well from a ſolution in ammonia. He obtained alſo the ſame colour from the nitrates of ſilver and of cobalt. The pruſſian colouring matter fixed by theſe metallic mordants reſiſted the action of acids, waſhings with ſoap, and expoſure to the weather for the greateſt length of time; but in all theſe caſes there muſt be a double application. The pruſſian colouring matter muſt firſt be applied to the linen, cotton or ſilk, which muſt be afterwards allowed to dry. It muſt then be immerſed in the metallic ſolution, or the metallic ſolution muſt be applied firſt, and then the ſolution of pruſſiate of potaſh, ſoda, lime, &c.

SECT. IV. *Of Dyeing Black.*

THE next of the ſimple colours is black, of which we ſhall treat as in the former ſections; firſt deſcribing the ſubſtances which are employed, and then giving an account

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* *Berthollet*, ii. 20.

* *Phil. of Perm. Col.* 217.

account of the proceſſes which are followed in dyeing different ſtuffs of a black colour.

I. *Of the Subſtances employed in Dyeing Black.*

Juices of plants.

326. There are few ſubſtances which have the property of producing a permanent black colour, without any addition. The juice of ſome plants produces this effect on cotton and linen. A black colour is obtained from the juice of the *caſhew nut*, which will not waſh out, and even reſiſts the proceſs of boiling with ſoap or alkalies. The caſhew nut of India is employed for marking linen. That of the Weſt Indies (*anacardium occidentale*, Lin.) alſo yields a permanent dye, but the colour has a browniſh ſhade. The juice of ſome other plants, as that of the toxicodendron, or ſloes, affords a durable blueiſh black colour; but theſe ſubſtances cannot be obtained in ſufficient quantity, even if they afforded colours equal to thoſe produced by the common proceſſes.

Tan, &c.

327. The principal ſubſtances which are employed to give a black colour are gall nuts which contain the aſtringent principle, or tan, and the red oxide of iron (R). For a particular account of the nature and properties of tan, ſee CHEMISTRY *Index*. The black colour is produced by the combination of the aſtringent principle with the oxide of iron, held in ſolution by an acid, and fixed on the ſtuff. When the particles are precipitated from the mixture of tan and a ſolution of iron, they have only a blue colour; but after they are expoſed for ſome time to the air, and moiſtened with water, the colour becomes deeper, although the blue ſhade is ſtill perceptible. After the particles are fixed on the ſtuff, the ſhade becomes much deeper.

328. Logwood is not to be conſidered as affording a black dye, but is much employed to give a luſtre to black colours. We have (180.) already deſcribed its nature and properties, among the ſubſtances from which red colouring matters are obtained.

Mordants neceſſary for black.

329. Black colours are rarely produced by a ſimple combination between the colouring matter and the ſtuff; but are uſually fixed by means of mordants, as in the caſe of the black particles which are the reſult of a combination of the aſtringent principle and the oxide of iron, held in ſolution by an acid. But when the particles are precipitated from the mixture of an aſtringent and a ſolution of iron, they have only a blue colour. By being expoſed to the air, and moiſtened with water, the colour becomes deeper, although the blue ſhade is ſtill perceptible. No fine black colour is ever obtained, unleſs the ſtuffs are freely expoſed to the air. In dyeing black, therefore, the operations muſt be conducted at different intervals. Berthollet has obſerved that black ſtuffs, when brought in contact with oxygen gas, diminiſh its volume, ſo that ſome portion of it is abſorbed.

II. *Of the Proceſſes for Dyeing Woollen Black.*

Muſt be firſt dyed blue.

330. In dyeing woollen ſtuffs black, if a full and fine deep colour is wanted, it is neceſſary that they are previouſly dyed of a deep blue colour. To remove all the particles of colouring matter which happen to be looſely attached to the ſtuff, it ſhould be waſhed in a river as ſoon as it is taken out of the vat, and afterwards cleanſed at the fulling mill. After theſe preliminary proceſſes, the ſtuffs are ready to receive the black colouring matter. The proceſs of Hellot is the following.

Hellot's proceſs.

For every hundred pounds of ſtuff, ten pounds of logwood, and ten pounds of galls reduced to powder, are put into a bag and boiled in a middle-ſized copper, with a ſufficient quantity of water, for 12 hours. A third of this bath is put into another copper, along with two pounds of verdigriſe. The ſtuff is immerſed in this bath, and continually ſtirred for 2 hours. The bath ſhould be kept hot, but it ought not to boil. At the end of two hours the ſtuff is taken out, and a ſimilar portion of the bath is put into the copper, with eight pounds of copperas (ſulphate of iron). During the ſolution of the copperas, the fire is diminiſhed, and the bath is allowed to cool for half an hour, ſtirring it well the whole time. The remainder of the bath is then to be added, and after making this addition, the bag containing the aſtringent matters ſhould be ſtrongly preſſed, to ſeparate the whole. A quantity of ſumach from 15 to 20 pounds, is now to be added, and the bath is juſt raiſed to the boiling temperature; and when it has given one boil, it is to be immediately ſtopped with a little cold water. A freſh quantity of ſulphate of iron, to the amount of two pounds, is then added, and the ſtuff is kept in it for another hour, after which it is taken out, waſhed and aired; it is again put into the copper, and conſtantly ſtirred for an hour. It is then carried to the river, well waſhed, and fulled. To ſoften the black colour, and make it more firm, another bath is prepared with weld. This is made to boil for a moment, and when it has cooled, the ſtuff is paſſed through it. By this proceſs, which is indeed ſomewhat complicated, a beautiful black colour is produced.

Common proceſs.

331. But the proceſſes uſually followed for dyeing black, are more ſimple. Cloth which has been previouſly dyed blue, is merely boiled in a vat of galls for two hours. It is then kept two hours, but without boiling, in the bath of logwood and ſulphate of iron, and afterwards waſhed and fulled. According to Hellot's proceſs, a bath is to be prepared of a pound and a half of yellow wood, five pounds of logwood, and ten pounds of ſumach, which is the proportion of the ingredients

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(R) Oak bark has been recommended as a ſubſtitute for gall-nuts in dyeing black, and particularly in dyeing hats; and it is ſaid that the colour thus obtained is fuller, more beautiful and durable, while the operation is eaſier and leſs liable to accident. It was firſt propoſed in the year 1782 by Stephanopoli, a Corſican, and a ſurgeon in the French army. The examination of the proceſs was referred by the French government to Macquer, who gave a favourable report of it; and afterwards to Berthollet, who gave a different opinion. The proceſs has ſince been examined, and promiſes to be more economical and advantageous, eſpecially for dyeing hats *.

* *Phil. Mag.* vi. 175.

gredients for every 15 yards of deep blue cloth; and the cloth having boiled in this bath for three hours, ten pounds of ſulphate of iron are added; the cloth is allowed to remain for two hours longer, when it is taken out to be aired, after which it is again returned to the bath for an hour, and then waſhed and fulled.

A cheaper proceſs.

332. When ſtuffs are to be dyed at a leſs expence, inſtead of the blue ground, a brown or root-coloured ground may be ſubſtituted. This brown or fawn colour is communicated by means of the root of the walnut tree, or green walnut peels. The ſtuffs are then to be dyed black, according to ſome of the proceſſes already deſcribed.

Proceſs of the Engliſh dyers.

333. The proportions of the ingredients employed by the Engliſh dyers are, for every hundred pounds of cloth previouſly dyed a deep blue, about five pounds of ſulphate of iron, five pounds of galls, and 30 of logwood. The firſt ſtep in the proceſs is to gall the cloth, after which it is paſſed through the decoction of logwood, to which the ſulphate of iron has been added.

Arbutus uſed for galls.

334. The leaves of the *arbutus uva urſi* have been recommended, and employed as a ſubſtitute for galls. The leaves muſt be carefully dried, ſo that the green colour may be preſerved. A hundred pounds of wool are boiled with 16 pounds of ſulphate of iron, and eight of tartar, for two hours. The day following the cloth is to be rinſed as after aluming. A hundred and fifty pounds of the leaves of *uva urſi* are then to be boiled for two hours in water, and after being taken out, a ſmall quantity of madder is to be added to the liquor, putting in the cloth at the ſame time, which is to remain about an hour and a half. It is then taken out and rinſed in water. †. By this proceſs, it is ſaid, blue cloth receives a pretty good black, but white cloth becomes only of a deep brown. It is ſaid, too, that the madder and tartar are uſeleſs ingredients.

Laſt operation.

335. After the different operations for dyeing the cloth have been finiſhed, it is waſhed in a river, and fulled, till the water comes off clear and colourleſs. Soap ſuds are recommended by ſome in fulling fine cloths, but it is found difficult to free the cloth entirely from the ſoap. After the cloth has come from the fulling mill, ſome propoſe to give it a dip in a bath of weld, by which it is ſaid to be ſoftened, and the colour better fixed; but according to Lewis, this operation, which in other caſes is of ſome advantage, is uſeleſs after the cloth has been treated with the ſoap ſuds.

III. *Of the Proceſſes for Dyeing Silk Black.*

336. In communicating a black colour to ſilk, different operations are neceſſary, ſuch as boiling, galling, repairing the bath, dyeing, and ſoftening.

337. To give a deeper ſhade to ſilk, it is neceſſary to deprive it of the gummy ſubſtance to which its ſtiffneſs and elaſticity are owing. This is done by boiling the ſilk four or five hours with one fifth its weight of white ſoap, and afterwards beetling and carefully waſhing it.

Galling.

338. In conducting the proceſs of galling ſilk, three fourths of its weight of galls are to be boiled for three or four hours, but the proportion of galls muſt depend on their quality. After the boiling, the liquor is allowed to remain at reſt for two hours; the ſilk is then put into the bath, and left there from 12 to 36 hours, when it is to be taken out, and waſhed in the river. But as ſilk is capable of combining with a great proportion of the aſtringent principle, or tan, from which it receives a conſiderable increaſe of weight, it is allowed to remain for a longer or ſhorter time, as the ſilk is required to have more or leſs additional weight. To communicate, therefore, to ſilk, what is called a *heavy* black, it is allowed to remain longer in the gall liquor; the proceſs is repeated oftener, and the ſilk is alſo dipped in the dye a greater number of times.

Dyeing.

339. While ſilk is preparing for the proceſs of dyeing, the bath is to be heated, and ſhould be occaſionally ſtirred, that the grounds which fall to the bottom may not acquire too much heat. It ſhould always be kept under the boiling temperature. Gum and ſolution of iron are added in different proportions, according to the different proceſſes. When the gum is diſſolved, and the bath near the boiling temperature, it is left to ſettle for about an hour. The ſilk, which in general is previouſly divided into three parts, that each may be ſucceſſively put into the bath, is immerſed in it. Each part is then to be three times wrung, and after each wringing hung up to air. The ſilk being thus expoſed to the action of the air, acquires a deeper ſhade. This operation being finiſhed, the bath is again heated, with the addition of gum and ſulphate of iron, and this is repeated two or three times, according as the black required is light or heavy. When the proceſs of dyeing is finiſhed, the ſilk is rinſed in a veſſel with ſome cold water, by turning or ſhaking it over.

Softening.

340. Silk, after it has been taken out of the dye, is extremely harſh, to remove which it is ſubjected to the operation of ſoftening. A ſolution of four or five pounds of ſoap for every hundred pounds of ſilk, is poured through a cloth into a veſſel of water. The ſolution being completed, the ſilk is immerſed, and allowed to remain in it for about 15 minutes; it is then to be wrung out and dried.

Dyeing raw ſilk.

341. When raw ſilk is to be dyed, that which has a natural yellow colour is preferred. The galling operation muſt be performed in the cold, if it be propoſed to preſerve the whole of the gum, and the elaſticity which it gives to the ſilk; but if part only of the gum is wiſhed to be preſerved, the galling is to be performed in the warm bath.

342. The dyeing operation is alſo performed in the cold. All that is neceſſary is to add the ſulphate of iron to the water in which the ſtuff is rinſed. By this ſimple proceſs the black dye is communicated. It is then waſhed, once or twice beetled, and dried without wringing, that its elaſticity may not be deſtroyed. Raw ſilk may be dyed by a more ſpeedy proceſs. After galling, it may be turned or ſhaken over in the cold bath; and thus by alternately dipping and airing the ſtuff, the operation may be completed. It is then to be waſhed and dried as in the former proceſſes.

A ſpeedier proceſs.

Improved proceſs for velvet.

343. The method of dyeing velvet at Genoa, which has been ſimplified and improved in France, is thus deſcribed by Macquer. For every 100 pounds of ſilk, 20 pounds of Aleppo galls, reduced to powder, are boiled in a ſufficient quantity of water for an hour. The bath is allowed to ſettle till the galls have fallen to the bottom; they are then taken out, and two pounds and a half of ſulphuric acid, twelve pounds of iron filings, and 20 pounds of gum, are put into a copper

† *Stockholm Tranſ.* 1753.

per veſſel, or cullender, furniſhed with two handles. This veſſel is immerſed in the bath, and ſupported that it may not touch the bottom. The gum, which is allowed to diſſolve for an hour, is to be occaſionally ſtirred; and if it appear that the whole of the gum is diſſolved, three or four pounds more are to be added. Excepting during the operation of dyeing, the cullender is to remain in the copper, which muſt be kept hot the whole time, but at a temperature below the boiling point. In galling the ſilk, one-third of Aleppo galls is employed, and the ſtuff ſhould remain ſix hours in the liquor the firſt time, and twelve hours the ſecond. By frequent additions of ſulphate of iron, and repeated immerſions of the ſtuff, a fine black, according to Lewis, has been obtained. In the above proceſs, the proportion of ſulphate of iron is too ſmall, and the gum, according to ſome, being carried off in the waſhing, may be conſidered as uſeleſs. Berthollet thinks that, although the quantity be exceſſive, it has ſome effect in keeping up the bath, and he adds, if it is to be diminiſhed, it would be uſeful to add the ſulphate of iron in ſeparate portions during each interval.

Subſtitute for galls.

344. To diminiſh the quantity of galls, which are an expenſive ingredient in dyeing ſilk black, other ſubſtances have been propoſed as ſubſtitutes. With this view the following proceſs is recommended.

The ſilk being boiled and waſhed, is immerſed in a ſtrong decoction of green walnut peels, and allowed to remain till the colouring matter of both is exhauſted. It is then to be ſlightly wrung out, dried and waſhed (M). To give the ſilk a blue ground, logwood and verdigriſe are employed, in the proportion of one ounce of the latter for every pound of ſilk. The verdigriſe is diſſolved in cold water, and the ſilk is allowed to remain two hours in this ſolution. It is then immerſed in a ſtrong decoction of logwood, ſlightly wrung out, dried, and afterwards waſhed at the river. The bath is prepared by macerating two pounds of galls and three of ſumach in 25 gallons of water, over a ſlow fire, for twelve hours. The liquid being ſtrained, three pounds of ſulphate of iron, and the ſame quantity of gum arabic, are to be diſſolved in it. The ſilk is dipped in this ſolution at two different times; it is to remain in the bath two hours each time, and it muſt be aired and dried between each dip. After being twice beetled at the river, it is dipped a third time, and left in the bath four or five hours, after which it is to be dried, waſhed and beetled as before. The temperature of the bath ſhould not exceed 120°. After the firſt dipping, it may be neceſſary to add half a pound of ſulphate of iron, and an equal quantity of gum arabic.

345. Silk which has been previouſly dyed blue with indigo, it is ſaid, takes only a mealy black; but when it has been prepared with logwood and verdigriſe, it acquires a velvety luſtre. A fine black may be obtained from green walnut peel; but the addition of logwood and verdigriſe renders a ſmaller quantity of ſulphate of iron neceſſary, and this is of importance, becauſe it is apt to weaken the ſilk. The only uſe of galls, according to ſome, is to increaſe the weight of the ſilk; for the purpoſes of dyeing, ſumach is conſidered ſufficient *.

* Berthollet, ii. 20.

IV. *Of the Proceſſes for Dyeing Cotton and Linen Black.*

Muſt be previouſly dyed blue.

246. It is more difficult to communicate a fine black to linen or cotton than to ſilk or woollen ſtuffs. To ſucceed in producing a black colour of that degree of intenſity which will reſiſt ſoap, it is neceſſary to adopt particular proceſſes. In dyeing animal matters black, as ſilk, and wool, the beſt colours are obtained on thoſe which have been previouſly dyed blue. This alſo is an eſſential preliminary proceſs in dyeing linen and cotton black; for it is found that the proceſs which ſucceeds beſt, is firſt to give a deep blue grain to the cotton or linen.

Galling.

347. The firſt part of the proceſs is the operation of galling. The ſtuffs which have been previouſly dyed blue, wrung out and dried, are kept 24 hours in the gall-liquor, compoſed of four ounces of galls to every pound of thread. A bath is then prepared of a ſolution of iron in acetic acid. This ſolution is obtained by ſaturating the acid with oxide of iron. In France, vinegar, ſmall beer, or ſmall wine, is employed for this purpoſe. To promote the acid fermentation, rye meal, or ſome other ſubſtance, is added, and pieces of old iron are thrown into the liquid, which are allowed to remain for ſix weeks or two months, that the acid may be ſaturated with the iron. This ſolution, called *iron liquor* in this country, is prepared from fermented worts, to which old iron is added, as is deſcribed above.

Dyeing.

Five quarts of the iron-liquor for every pound of ſtuffs, are put into a veſſel. In this the ſtuffs are wrought with the hand, pound by pound, for 15 minutes: they are then wrung out and aired. This operation is to be again repeated, taking care to add a freſh quantity of the iron-liquor, which ſhould be carefully ſcummed, after which the ſtuffs are to be wrung out, aired, and waſhed at the river. In the next operation, a pound of alder bark for every pound of ſtuff is boiled in a ſufficient quantity of water for an hour. One half of the bath which was employed in the galling, and about one half the quantity of ſumach as of alder bark, are then added. The whole is boiled together for two hours, and ſtrained through a ſieve. When this liquid is cold, the ſtuffs are immerſed, wrought pound by pound, and occaſionally aired. They are afterwards put into the bath, and after remaining for 24 hours, are wrung out and dried. The above is the proceſs which, according to D'Apligny, is followed at Rouen, for dyeing cotton and linen.

Another proceſs.

348. The proceſs followed at Mancheſter, which is deſcribed by Mr Wilſon, is the following. For the operation of galling, galls or ſumach are employed. The ſtuff is afterwards dyed in a bath conſiſting of a ſolution of iron in acetic acid. This bath is alſo frequently compoſed of alder bark and iron. After having paſſed through this bath, the ſtuff is dipped in a decoction of logwood, to which a ſmall quantity of verdigriſe has been added. This proceſs is to be repeated

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(M) The decoction of walnut peels is prepared by boiling for 15 minutes, after which it is taken from the fire. After it has ſubſided, the ſilk, which has been previouſly immerſed in warm water, is dipped in it.

peated till a black of ſufficient intenſity is obtained, obſerving to waſh and dry after each operation.

Preparation of ſolution of iron.

349. According to Guhliche, a ſolution of iron may be prepared by the following proceſs. A pound of rice is to be boiled in 12 or 15 quarts of water, till the whole is diſſolved. A ſufficient quantity of old iron made red hot, to reach half way to the ſurface of the liquor, is thrown into the ſolution. The veſſel in which the ſolution is kept muſt be under cover, but expoſed to the air and light at leaſt for a week. In another veſſel, containing a quantity of warm vinegar equal to the ſolution of rice, an equal quantity of red-hot iron is to be put. This veſſel muſt alſo be expoſed in the ſame way to the air and light. After ſeveral days, the contents of both veſſels are mixed together, and the mixture is to be expoſed for a week to the open air, after which it is to be decanted and kept for uſe in a cloſe veſſel. To give a ſufficient black to linen and cotton, it is only neceſſary, it is ſaid, to ſteep them 24 hours in this ſolution; and if it ſhould appear that the liquor is exhauſted of colouring matter, a freſh portion is to be employed. In this way a fine permanent black is obtained. According to the ſame author, this ſolution may be advantageouſly employed as a ſubſtitute for ſulphate of iron, in dyeing ſilk and wool. But to give them a fine black, ſilk and woollen ſtuffs muſt be dipped in a decoction of logwood after they are taken from the bath.

Its application.

Sect. V. *Of Brown.*

350. The laſt of the ſimple colours is brown. This is alſo known under the name of *fawn* colour, (*fauve*, Fr.) It is that brown colour which has a ſhade of yellow, and might perhaps be conſidered as a compound colour, although it is communicated to ſtuffs by one proceſs.

I. *Of the Subſtances employed in Dyeing Brown.*

351. The vegetable ſubſtances which are capable of inducing a fawn or brown colour on different ſtuffs, are very numerous, but thoſe chiefly employed for this purpoſe are walnut peels and ſumach. The peels conſtitute the green covering of the nut; they are internally of a white colour, which is converted into brown or black by expoſure to the air. The ſkin when impregnated with the juice of walnut peels, becomes of a brown or almoſt black colour. When the inner part of the peel, taken freſh, is put into weak oxymuriatic acid, it aſſumes a brown colour. If the decoction of walnut peels be filtered and expoſed to the air, its colour becomes of a deep brown; the pellicles on evaporation are almoſt black; the liquor detached from theſe yields a brown extract completely ſoluble in water. The colouring particles are precipitated from a decoction of walnut peels, by means of alcohol, and they are ſoluble in water. No apparent change is at firſt produced by a ſolution of potaſh; but it gradually becomes turbid, and the colour is deepened. A copious precipitate of a fawn colour, approaching to an aſh colour, is produced in a decoction of walnut peels by means of a ſolution of tin, and the remaining liquor has a ſlightly yellow tinge.

Walnut peels.

Properties.

352. A decoction of walnut peels yields a ſmall quantity of fawn-coloured precipitate by means of a ſolution of alum, and the liquor remains of the ſame colour. Sulphate of copper renders it ſlowly turbid, and throws down a ſmall quantity of precipitate of a browniſh green colour, leaving the ſupernatant liquor of the ſame colour. Sulphate of iron deepens the colour; when diluted, the colour becomes browniſh green, without the depoſition of any ſediment. Sulphate of zinc alſo deepens the colour, and produces no precipitate. The ſame properties are exhibited by a decoction of the walnut-tree wood, but the colouring matter is not obtained from it in ſuch abundance as from the peels; and the bark may alſo be uſed with advantage in dyeing.

Advantages

353. The affinity of the colouring matter of walnut peels for wool is very ſtrong; and it readily imparts to it a durable colour, which even mordants do not ſeem capable of increaſing, but they are generally underſtood to give it additional brightneſs. A lively and very rich colour is obtained with the aſſiſtance of alum. Walnut peels afford a great variety of pleaſing ſhades, and as they require not the intervention of mordants, the ſoftneſs of the wool is preſerved, and the proceſs of dyeing becomes both cheap and ſimple.

Preparation

354. Walnut peels are not gathered till the nuts are completely ripe, when they are put into large caſks, along with as much water as is ſufficient to cover them. When uſed in dyeing at the Gobelins in Paris, Berthollet informs us, they are kept for upwards of a year, and very extenſively uſed; but if not made uſe of till the end of two years, they yield a greater quantity of colouring matter, at which time their odour has become peculiarly diſagreeable and fetid. The peels ſeparated from the nuts before they arrive at maturity, may likewiſe be uſed in dyeing, but in this ſtate they do not keep ſo long.

Sumach.

355. Sumach (*rhus coriaria*, Linn.) is a ſhrub produced naturally in Paleſtine, Syria, Portugal, and Spain, being carefully cultivated in the two laſt of theſe countries. Its ſhoots are annually cut down, dried, and reduced to powder in a mill, by which proceſs they are prepared for the purpoſes of dyeing.

Properties.

356. The infuſion of ſumach, which is of a fawn colour with a greeniſh tinge, is changed into a brown by expoſure to the air. A ſolution of potaſh has little action on the recent infuſion of ſumach; its colour is changed to yellow by the action of acids; the liquor becomes turbid by means of alum, a ſmall quantity of precipitate being at the ſame time formed, and the ſupernatant liquor remaining yellow. A copious precipitate of a yellowiſh green colour is thrown down by ſulphate of copper, and the liquor remains clear. No change is ſpeedily produced by muriate of ſoda (common ſalt), but it becomes rather turbid at the end of ſome hours, and its colour is rather clearer. Sulphate of copper produces a copious precipitate of a yellowiſh green, which after ſtanding ſome hours, changes to a browniſh green; the ſupernatant liquor, which is ſlightly yellow, remains clear. Sulphate of zinc renders the liquor turbid, darkens its colour, and produces a deep blue precipitate; but when the ſulphate of zinc is pure, the precipitate, which is of a browniſh fawn colour, is in very ſmall quantity. Acetate of lead gives a copious precipitate, of a yellowiſh colour; the ſupernatant liquor is of a clear yellow colour. No aſtringent has ſo ſtrong a reſemblance to galls as ſumach; but the precipitate

precipitate thrown down from an infuſion of it by a ſolution of iron, is not ſo copious as that which is yielded by an equal quantity of galls, on which account ſumach may be generally employed as a ſubſtitute for galls, only its quantity will require to be increaſed.

Bark of birch.

357. The bark of the birch-tree (*betula alba*, Lin.) yields a decoction of a clear fawn colour, but it ſoon becomes turbid and brown. The addition of a ſolution of alum in the open air, produces a copious yellow precipitate; a ſolution of tin gives alſo a copious precipitate of a clear yellow colour. With ſolutions of iron the decoction of the birch-tree ſtrikes a black colour, and it diſſolves in conſiderable quantity the oxide of iron, but in ſmaller proportion than the decoction of walnut peels. On account of this property it is employed in the preparation of black vats for dyeing thread.

Sandal wood.

358. Saunders, or ſandal wood, is alſo employed for the purpoſe of giving a fawn colour. There are three kinds of ſandal wood, the white, the yellow, and the red. The laſt only, which is a compact heavy wood, brought from the Coromandel coaſt, is uſed in dyeing. By expoſure to the air it becomes of a brown colour; when employed in dyeing, it is reduced to fine powder, and it yields a fawn colour with a browniſh ſhade, inclining to red. But the colouring matter which it yields of itſelf is in ſmall quantity, and it is ſaid that it gives harſhneſs to woollen ſtuffs. When it is mixed with other ſubſtances, as ſumach, walnut peels, or galls, the quantity of colouring matter is increaſed; it gives a more durable colour, and produces conſiderable modifications in the colouring matter with which it is mixed. Sandal wood yields its colouring matter to brandy, or diluted alcohol, more readily than to water.

Soot.

359. Soot communicates to woollen ſtuffs a fawn or brown colour, of a lighter or deeper ſhade, in proportion to the quantity employed; but the colour is fading, and its affinity for wool is not great; and beſides leaving a diſagreeable ſmell, it renders the fibres harſh. In ſome manufactories, it is employed for browning certain colours, and it produces ſhades which could not otherwiſe be eaſily obtained.

II. *Of the Proceſſes for Dyeing Woollen*, &c. *a Fawn or Brown Colour.*

With walnut peels.

360. In dyeing with walnut peels, a quantity proportioned to the quantity of ſtuff, and the intenſity of ſhade wanted, is boiled for fifteen minutes in a copper. All that is neceſſary in dyeing with this ſubſtance is, to moiſten the cloth or yarn with warm water, previous to their immerſion in the copper, in which they are to be carefully ſtirred till they have acquired the proper ſhade. This is the proceſs, if the aluminous mordant is not employed. In dyeing cloth, it is uſual to give the deepeſt ſhades firſt, and the lighter ones afterwards; but in dyeing woollen yarn, the light ſhades are given firſt, and the deeper ones afterwards. An additional quantity of peels is joined to each parcel.

Berthollet's experiments.

361. Berthollet made a number of experiments to aſcertain the difference of colour obtained from the ſimple decoction of walnut peels, and the addition of metallic oxides as mordants. The oxide of tin, he found, yielded a clearer and brighter fawn colour than that of the ſimple decoction. The oxide of zinc produced a ſtill clearer colour, inclining to aſh or gray. The colour from oxide of lead had an orange caſt, while that from oxide of iron was of a greeniſh brown *.

Dyeing with ſumach.

362. A fawn colour, which has a ſhade of green, is obtained from ſumach alone; but to cotton ſtuffs which have been impregnated with printers mordant, or acetate of alumina, ſumach communicates a good and durable yellow. Here, however, ſome precaution is neceſſary in the uſe of this ſubſtance for this purpoſe; for as the colouring matter is of ſo fixed a nature, the ground of the ſtuff cannot be bleached by expoſure on the graſs. This inconvenience is avoided by impregnating the whole of the ſtuff with different mordants, producing in this way a variety of colours, and leaving no part white.

With ſandal wood.

363. Vogler employed the tincture of ſaunders wood for dyeing patterns of wool, ſilk, cotton, and linen, having previouſly impregnated them with a ſolution of tin, and afterwards waſhing and drying them. Sometimes he uſed the ſolution unmixed, and at other times added ſix or ten parts of water, and in whatever way he employed it, he obtained a poppy colour. When the mordant employed was ſolution of alum, the colour was a rich ſcarlet; with ſulphate of copper it was a clear crimſon, and with ſulphate of iron a beautiful deep violet †.

CHAP. II. *Of Compound Colours.*

Nature of compound colours.

364. A MIXTURE of two colouring ſubſtances, it is well known, produces a very different ſhade from that of either of the uncombined colouring matters; hence compound colours are obtained, which are merely mixtures of ſimple colours. It would undoubtedly be a deſirable thing to aſcertain with accuracy the peculiar ſhade produced by the combination of two colouring matters; but theſe reſults can only be certainly known by experiment, becauſe by the action of different ſubſtances in the baths, they are ſubject to great variations in their effects, according to the affinities which are brought into action, and the new combinations which are formed. What is natural to colouring particles is not to be conſidered as a conſtituent part of compound colours, but only the difference of ſhade which they ought to aſſume, with a particular mordant, or in a particular bath. The effects, therefore, of the chemical agents employed in theſe proceſſes, and the reſult of different combinations, ought to be particularly attended to. It is in dyeing compound colours that ſkill and ingenuity are moſt conſpicuous, and their application of greateſt utility, to enable the dyer to vary his proceſſes, according to the ſhade deſired, and at the ſame time to accompliſh his operations by the ſhorteſt and cheapeſt means.

Great variety of ſhade.

365. As compound colours are obtained by the mixture of ſimple colours, very different ſhades will be obtained from different proportions of the ſimple colours; hence compound colours exhibit an indefinite variety of ſhade, and the proceſſes by which they are produced are very numerous. It would extend this treatiſe to an unuſual length, were we to attempt to deſcribe every variety of ſhade which is obtained from the mixture of ſimple colours. We ſhall therefore limit our obſervations to ſome of the principal compound colours, and an

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* Elements of Dyeing, ii. 296.

† Crell Ann. 1790.

an account of the proceſſes by which they are obtained, leaving it to our readers, who have made themſelves familiar with the principles already detailed, to vary theſe colours, by employing different proportions and different combinations of ſimple colouring matters.

366. Compound colours have been uſually divided into four claſſes, namely, green, purple, orange, and gray or drab colour. Theſe are obtained from mixtures of the following ſimple colours.

1. Blue and yellow produce a green.
2. Red and blue, a purple, &c.
3. Red and yellow, orange.
4. Black and other colours, gray, &c.

The following ſections will be occupied in a ſhort detail of the methods which are uſually employed in producing theſe different compound colours.

Sect. I. *Of the Mixture of Blue and Yellow, or Green.*

Various ſhades of green.

367. Green colours, from the great variety of ſhades which they exhibit, have been long known by different names, by which the intenſity of ſhade is characteriſed, ſuch as ſea-green, apple-green, meadow or graſs green, pea-green, parrot-green, &c. Many plants afford a green colour, ſuch as brome graſs (*bromus ſecalinus*, Lin.), green berries of *rhamnus frangula*, wild chervil (*chærophyllum ſylveſtre*, Lin.), purple clover (*trifolium pratenſe*), common reed (*arundo phragmites*). Theſe colours, however, do not poſſeſs ſufficient permanency. According to D'Ambourney, indeed, a permanent green may be obtained from the fermented juice of the berries of the berry-bearing alder (*rhamnus frangula*). Having previouſly prepared the cloth with tartar, ſolution of nitrate of biſmuth and common ſalt, he added to the fermented juice of the berries, after it was warmed, a ſmall proportion of acetate of lead; and in this bath he communicated to the cloth an intermediate ſhade between parrot and graſs green. But it is uſually from the mixture of blue and yellow that green is obtained; and it may be obſerved, that it requires much ſkill and experience, eſpecially in giving light ſhades, to produce a colour which is uniform, and entirely without ſpots.

I. *Of the Proceſſes for Dyeing Woollen Stuffs Green.*

Common proceſs.

368. To dye woollen green, either the yellow or the blue dye may be given to it firſt. But when the ſtuff is firſt dyed yellow, and in this ſtate is introduced into the blue vat, part of the yellow colouring matter being diſſolved in the vat, communicates to it a green colour, which renders it unfit for dyeing any other colour than green. To avoid this inconvenience, therefore, the blue colour is firſt given, and afterwards the yellow. It would be quite unneceſſary to reſume the account of any part of the proceſſes for dyeing blue, which have been already detailed. It is proper, however, to add, that the intenſity of the blue ſhade muſt be proportioned to the green, or to the depth of the green colour which is wiſhed to be obtained. Thus, for inſtance, to produce a parrot green, a ground of ſky blue is given, and for the green like that of a drake's neck, a deep blue is required. When the blue dye has been communicated, the yellow is afterwards given, according to ſome of the proceſſes which have been already deſcribed for dyeing yellow. The proper ground being communicated to the cloths, they are waſhed in the fulling mill, and boiled as for the common proceſs of welding; but when the ſhade is light, the proportion of ſalts ſhould be leſs. Cloths which are to receive light ſhades are firſt boiled, and when theſe are taken out, tartar and alum are added in freſh portions, till the cloths which are intended for the darkeſt ſhades are boiled. The proceſs of welding is conducted in the ſame way as for dyeing yellow, with this difference, that a larger proportion of weld is employed, excepting for lighter ſhades, when the proportion muſt be ſmaller. In dyeing green, it is uſual to have a ſucceſſion of ſhades at the ſame time; the proceſs is begun with the deepeſt, and ends with the lighteſt. Between each dip there ſhould be an interval of one-half or three-quarters of an hour, and at each interval water is added to the bath. It is the practice of ſome dyers to give each parcel two dips, beginning the firſt time with the deep ſhades, and the ſecond with the lighter ones; but when this practice is followed, the time of immerſion ſhould be ſhortened. In dyeing very light ſhades, the bath ſhould never be permitted to reach the boiling temperature. For deep greens, a browning is given with logwood, and a ſmall proportion of ſulphate of iron.

Saxon green.

369. For ſome kinds of green, ſulphate of indigo is employed; and in this caſe either the blue and yellow are dyed ſeparately, or the whole of the ingredients are mixed together in the bath, and the whole proceſs is finiſhed at a ſingle operation. The colour thus obtained has been diſtinguiſhed by the name of *Saxon green*. The following is the proceſs recommended by Dr Bancroft.

370. "The moſt beautiful Saxon greens (ſays he) may be produced very cheaply and expeditiouſly, by combining the lively yellow which reſults from quercitron bark, murio-ſulphate of tin, and alum, with the blue afforded by indigo when diſſolved in ſulphuric acid, as for dyeing the Saxon blue.

"To produce this combination moſt advantageouſly, the dyer, for a full-bodied green, ſhould put into the dyeing veſſel after the rate of ſix or eight pounds of powdered bark, in a bag, for every 100 lb. weight of cloth, with only a ſmall proportion of water as ſoon as it begins to grow warm; and when it begins to boil, he ſhould add about ſix pounds of murio-ſulphate of tin (with the uſual precautions), and a few minutes after, about four pounds of alum; theſe having boiled together five or ſix minutes, cold water ſhould be added, and the fire diminiſhed ſo as to bring the heat of the liquor nearly down to what the hand is able to bear; and immediately after this, as much ſulphate of indigo is to be added as will ſuffice to produce the ſhade of green intended to be dyed, taking care to mix it thoroughly with the firſt ſolution by ſtirring, &c.; and this being done, the cloth previouſly ſcoured and moiſtened, ſhould be expeditiouſly put into the liquor, and turned very briſkly through it for a quarter of an hour, in order that the colour may apply itſelf equally to every part, which it will certainly do in this way with proper care. By theſe means, very full, even, and beautiful greens may generally be dyed in half an hour; and during this ſpace, it is beſt to keep the liquor at rather leſs than a boiling heat. Murio-ſulphate of of tin is infinitely preferable, for this uſe, to the dyer's ſpirit; becauſe the latter conſiſts chiefly of nitric acid, which by its highly injurious action upon indigo, would render that part of the green colour very fugitive, as I have found by repeated trials. But no ſuch effect can reſult from the murio-ſulphate of tin, ſince the muriatic acid has no action upon indigo; and the ſulphuric is that very acid which alone is proper to diſſolve it for this uſe.

“ Reſpecting the beauty of the colour thus produced, thoſe who are acquainted with the unequalled luſtre and brightneſs of the quercitron yellows, dyed with the tin baſis, muſt neceſſarily conclude, that the greens compoſed therewith will prove infinitely ſuperior to any which can reſult from the dull muddy yellow of old fuſtic; and in point of expence, it is certain that the bark, murio-ſulphate of tin, and alum, neceſſary to dye a given quantity of cloth in this way, will coſt leſs than the much greater quantity (ſix or eight times more) of fuſtic, with the alum neceſſary for dyeing it in the common way, the ſulphate of indigo being the ſame in both caſes. But in dyeing with the bark, the veſſel is only to be filled and heated once; and the cloth, without any previous preparation, may be completely dyed in half an hour; whilſt in the common way of producing Saxon greens, the copper is to be twice filled; and to this muſt be joined the fuel and labour of an hour and a half's boiling and turning the cloth, in the courſe of preparation, beſides nearly as much boiling in another veſſel to extract the colour of the fuſtic; and after all the dyeing proceſs remains to performed, which will be equal in time and trouble to the whole of the proceſs for producing a Saxon green with the bark; ſo that this colour obtained from bark will not only prove ſuperior in beauty, but in cheapneſs, to that dyed as uſual with old fuſtic *.”

II. *Of the Proceſſes for Dyeing Silk Green.*

Preparation.

371. In giving ſilk a green colour, greater precaution is neceſſary, to preſerve uniformity of colour, and to prevent ſpots and ſtripes. Silk which is intended to receive a green colour, is ſcoured in the ſame way as for other colours; but for light ſhades, the ſcouring muſt be as complete as for blue. Silk which is to be dyed green, is firſt dyed yellow, and being well alumed, it is ſlightly waſhed at the river, and divided into ſmall parcels, that it may receive the colouring matter uniformly, and then carefully turned in the weld bath. When the ground is ſuppoſed to have acquired a ſufficient degree of intenſity, a pattern is put into the blue vat, to aſcertain the proper ſhade. When this is the caſe, the ſilk is taken out of the bath, waſhed, and immerſed in the blue vat. To produce a deeper colour, and at the ſame time to give variety of ſhade, a decoction of logwood, fuſtic, or anotta, is added to the yellow bath, after the weld has been taken out. For very light ſhades, ſuch as apple and ſea green, it is ſcarcely neceſſary to add, that a weaker ground is to be given. For all light ſhades except ſea green, the proceſs is found to ſucceed better when the yellow is communicated by baths which have been already uſed; but theſe baths ſhould not contain any logwood or fuſtic.

Saxon green.

372. Saxon green is produced by means of ſulphate of indigo. This is a brighter, but leſs durable colour than the former. This proceſs is conducted by boiling as for welding, after which the cloth is waſhed. Fuſtic in chips is encloſed in a bag, put into the ſame bath, and boiled for an hour and a half, when it is taken out, and the bath allowed to cool till the hand can bear it. A pound and a quarter of ſulphate of indigo for each piece of cloth of eighteen yards, is added. The cloth is at firſt to be turned quickly, and afterwards more ſlowly, and it ſhould be taken out before the bath boils. Some dyers put in only two-thirds of the ſolution at firſt; and after two or three turns, take out the cloth, and add the other one-third. By this means the colour is more uniform.

By one operation.

373. To produce Saxon green at one operation, the following proceſs is recommended by Dr Bancroft. A bath is prepared of four pounds of quercitron bark, three pounds of alum, and two pounds of murio-ſulphate of tin, with a ſufficient quantity of water. The bath is boiled ten or fifteen minutes, and when the liquor is ſo far reduced in temperature as the hand can bear it, it is fit for dyeing. By adding different proportions of ſulphate of indigo, various and beautiful ſhades of green may be obtained, and the colour thus produced is both cheap and uniform. Care ſhould be taken to keep the bath conſtantly ſtirred, to prevent the colouring matter from ſubſiding. Thoſe ſhades which are intended to incline moſt to the yellow, ſhould be dyed firſt; and by adding ſulphate of indigo, the green, having a ſhade of blue, may be obtained. This proceſs, Dr Bancroft obſerves, is the moſt commodious and certain for dyeing the moſt beautiful Saxon greens upon ſilk †.

Engliſh green.

374. To produce Engliſh green, which is more beautiful than common green, and is ſaid to be more durable than the Saxon green, Guhliche gives the following proceſs. He firſt dyes the ſilk of a light-blue in the cold vat already deſcribed (316.), then ſoaks it in warm water, waſhes it in a ſtream, and dips it in a weak ſolution of alum. He then prepares a bath of ſulphate of indigo, one ounce of ſolution of tin, with the tincture of French berries made with aceto-citric acid. The ſilk is kept in this bath till it has obtained the deſired colour. It is then waſhed and dried in a ſhady place. Lighter ſhades may be dyed afterwards ‡.

III. *Of the Proceſſes for Dyeing Cotton and Linen Green.*

Blue firſt given.

375. Cotton and linen, after being ſcoured in the uſual way, are firſt dyed blue; and after being cleanſed, they are dipped in the weld bath, to produce a green colour. The ſtrength of the blue and yellow is proportioned to the ſhade of green which is wanted. But as it is difficult to give to cotton velvet an uniform colour in the blue vat, it is firſt dyed yellow with turmeric, and the proceſs is completed by giving it a green with ſulphate of indigo. The ſame reſult, however, will be obtained by commencing the proceſs either with the yellow or the blue.

Proceſs for cotton velvet.

376. The proceſs which D'Apligny deſcribes for dyeing cotton velvet, or cotton thread a ſea or apple-green in one bath is the following. A quantity of verdigriſe is diſſolved in vinegar, and the mixture is kept excluded from the air in the heat of a ſtove for fifteen days. A quantity of potaſh equal in weight to the verdigriſe employed is diſſolved in water, and four hours

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* Phil. of Perm. Col. 336.

† Phil. Perm. Col. 346.

‡ Berthollet, ii. 319.

Compound Colours.

hours before dyeing it is added to the ſolution of verdigriſe. This mixture is to be kept hot. One ounce of alum in five quarts of water for each pound of ſtuff being prepared, the cotton thread or velvet is ſoaked in this ſolution. It is then taken out, and the verdigriſe mixture being added to the ſolution of alum, it is again introduced to be dyed.

Olive green.

377. The different ſhades of olive green, and drake's neck green, are given to thread after it has received a blue ground, by galling it, and dipping it in a weaker or ſtronger bath of iron liquor, then in the weld bath, to which verdigriſe has been added, and afterwards in the bath with ſulphate of copper. The colour is laſtly to be brightened with ſoap.

Green from Pruſſian blue.

378. Cotton dyed with Pruſſian blue may be dyed green by previouſly aluming while it is ſtill wet with the blue, and then dipping in a weld bath, the ſtrength of which is proportioned to the ſhade required. The colour from weld is more lively than that obtained from fuſtic. But fuſtic which gives a deeper ſhade than weld, and diminiſhes the brightneſs of the blue, is to be preferred when a green with an olive ſhade is wanted.

General remarks.

379. The ſhade of green given to any ſtuff, it is obvious, muſt vary according to the intenſity of the blue ſhade, the ſtrength of the yellow bath, and the nature of the yellow colouring matter employed. Yellow colours are rendered more intenſe by means of alkalies, ſulphate of lime and ammoniacal ſalts; but become fainter by means of acids, alum, and ſolutions of tin. In dyeing Saxon green the reſult will be different according to the proceſs which is followed. The effects will be different by adding a yellow to a Saxon blue, from the proceſs in which the ſulphate of indigo is mixed with the yellow ingredients; becauſe in the latter caſe the ſulphuric acid has a conſiderable action on the colouring matter, and thus diminiſhes the intenſity of the yellow. As the particles of indigo have a ſtronger affinity for the ſtuff than the yellow colouring matter, in dyeing a ſucceſſion of ſhades in a bath in which both are mixed, the bath being firſt exhauſted of the indigo, the laſt ſhades incline more to the yellow on account of the predominance of the yellow colouring matter.

Sect. II. *Of the Mixture of Red and Blue, or Purple*, &c.

380. By the mixture of red and blue, violet, purple, dove-colour, lilac, and a great variety of other ſhades, according to the proportions of the ſubſtances employed, or the predominance of the blue or the red, are produced. In ſtuffs which are to be dyed violet, a deeper blue muſt be given, but for purple colours, the ground requires to be of a lighter blue; but in lilac and ſimilar light colours, it is neceſſary that both the blue and the red have a light ſhade.

I. *Of Dyeing Wool Violet, Purple*, &c.

Blue firſt given.

381. In the attempts which have been made to communicate a violet or purple colour to a ſcarlet ground, according to the obſervations of Hellot, the colour is very unequal. It becomes therefore neceſſary to give the blue colour firſt; and for violets and purples, the ſhade of blue ought not to be deeper than that of ſky blue. The ſtuff being dyed blue, is boiled with alum, and two fifths of tartar, and is afterwards dipped in a bath compoſed of nearly two thirds the quantity of cochineal required for ſcarlet, with the addition of tartar. The ſame proceſs, indeed, as for dyeing ſcarlet, is followed. It is a common practice to dye theſe colours after the reddening for ſcarlet, making ſuch additions of cochineal and tartar as the intenſity of the ſhade may require.

Compound Colours.

Lilac, &c.

382. For lighter ſhades, as lilacs, dove-colours, &c. the ſtuff may be dipped in the bath which has ſerved for violet and purple, and is now ſomewhat exhauſted, taking care to add a quantity of alum and tartar. For reddiſh ſhades, ſuch as peach bloſſom, a ſmall proportion of ſolution of tin is added. It may be obſerved, in general, that although the proportion of cochineal is leſs in dyeing lighter ſhades, the quantity of tartar muſt not be diminiſhed.

Cheaper and ſhorter proceſs.

383. To obtain the ſame colours, a ſhorter and leſs expenſive proceſs is recommended by Poerner. In this proceſs he employs ſulphate of indigo. He boils the ſtuff in a ſolution of alum, in the proportion of three ounces of the latter to one pound of the former, for an hour and a half, and afterwards allows it to remain in the liquid for a night after it has cooled. The dyeing bath is prepared with an ounce and a half of cochineal, and two ounces of tartar, which are boiled for three quarters of an hour: two ounces and a half of ſulphate of indigo are then added, the whole is ſtirred, and boiled gently for 15 minutes. The dyeing operation is conducted in the uſual way, and a beautiful violet is thus obtained. To have all the variety of ſhades which are produced by the mixture of red and blue, the proportion of the ſulphate of indigo is increaſed or diminiſhed. It is ſometimes increaſed to five ounces, and diminiſhed to five drachms, for each pound of ſtuff. The quantity of cochineal is alſo varied, but when it is leſs than an ounce, the colour is dull. Different proportions of tartar are alſo employed. To produce variety of ſhades, the ſtuff is alſo prepared with different proportions of ſolution of tin.

Purple from logwood.

384. To communicate a purple colour to wool, as well as ſome other ſhades, logwood, with the addition of galls, has been employed. The ſtuff is previouſly dyed blue, and to give a brown ſhade, ſulphate of iron is uſed; but the colours thus obtained are not permanent. By the following proceſs, deſcribed by Decroizille, a durable dye is produced, by means of this wood. He diſſolved tin in ſulphuric acid, to which were added common ſalt, red acidulous tartrite of potaſh, and ſulphate of copper; or it may be more conveniently done by making a ſolution of tin in a mixture of ſulphuric acid, common ſalt, and water, to which are to be added the tartrite and ſulphate in the ſtate of powder. Of this mordant not leſs than 1500 quarts were made in twenty four hours, in a leaden veſſel to which a moderate heat was applied. A very lucrative trade was carried on for three years by Decroizille, who ſold it at the rate of 1s. 3d. ſterling per pound.

Proceſs.

385. If wool in the fleece is to be dyed, it will require a third of its weight of this mordant, while a fifth is a proportion ſufficient for ſtuffs. A bath is prepared of ſuch a degree of temperature as the hand can bear, with which the mordant is properly mixed, and the wool or ſtuff dipped in it and ſtirred, the ſame degree of

of temperature being kept up for two hours, and increaſed a little towards the end; after which it is taken out, aired, and well waſhed. A freſh bath of pure water is prepared at the ſame temperature, to which is added a ſufficient quantity of the decoction of logwood; the ſtuff is then immerſed, ſtirred, and the heat increaſed to the boiling temperature, which is to be continued for 15 minutes, after which the ſtuff being taken out, aired, and carefully rinſed, the proceſs of dyeing is completed. If for every three pounds of wool, one pound of a decoction of logwood has been uſed, and a proportionate quantity for ſtuffs which require leſs, a fine violet colour is produced, to which a ſufficient quantity of braſil-wood imparts the ſhade known in France by the name of *prune de Monſieur*.

Different ſhades from other ſubſtances.

386. Logwood and braſil, fuſtic and yellow wood, are colouring ſubſtances which may be fixed with advantage upon wool by means of this mordant. The colour communicated by the two firſt of theſe is liable to be changed in the fulling by the action of the ſoap or urine employed for that purpoſe; but this change, which is always produced by alkaline ſubſtances, is remedied by a ſlightly acid bath a little hot, called *brightening*, for which the ſulphuric acid has the preference. The colour becomes as deep, and frequently much brighter than before the change. Wools which have been dyed by means of this mordant, are ſaid to admit of being ſpun into a finer and more beautiful thread, than by the uſe of alum. If the uſe of ſulphate of copper is omitted, more beautiful colours are produced by fuſtic and yellow wood, as well as by weld. An orange red colour is communicated by madder, but not ſo deep as with a ſimilar quantity of alum. When ſulphate of copper is omitted, the wool is ſaid to become much harſher, and the mordant thus prepared yields but indifferent colours with logwood, and in particular with braſil-wood. The uſe and carriage of this mordant are inconvenient, on account of the heavy ſediment by which the veſſel is half filled under a corroſive liquor, capable only of being kept in ſtone ware. Theſe inconveniences may be remedied by the omiſſion of the water in the receipt, which leaves only a paſte more conveniently uſed, and the carriage of it two-fifths cheaper.

Nature of the proceſs.

387. The above proceſs is thus explained by Berthollet. The decompoſition of the muriate of ſoda is effected by the action of the ſulphuric acid, and the muriatic acid being thus diſengaged, diſſolves the tin, part of which is precipitated by means of the tartaric acid, producing the ſediment already mentioned. The oxide of copper produces the blue with the colouring particles of the logwood; the violet is formed by the oxide of tin with the ſame wood, and the red, with the colouring matter of the braſil-wood. The ſame ingenious chemiſt farther obſerves, that as an exceſs of acid is retained in the liquor, it might probably be of advantage to employ acetate as a ſubſtitute for ſulphate of copper, in which caſe the action of the free acid would be moderated. He thinks it would ſtill be more adviſeable to make uſe of verdigriſe; becauſe the uncombined part of the oxide of copper would, in that caſe, unite with the exceſs of acid, on which account a ſmaller quantity of acid would remain in the liquor; and probably the quantity of tartar might be diminiſhed, as a ſmaller quantity of tin would thus be precipitated *.

II. *Of Dyeing Silk Violet or Purple.*

Two kinds of violet.

388. Silk is capable of receiving two kinds of violet colours, denominated the fine and the falſe, the latter of which is produced by means of archil or braſil-wood. When the fine violet colour is required, the ſilk muſt firſt be paſſed through cochineal, and dipped afterwards in the vat. The preparation and dyeing of the ſilk with cochineal are the ſame as for crimſon, with the omiſſion of tartar and ſolution of tin, by means of which the colour is heightened. The quantity of cochineal made uſe of is always proportioned to the required ſhade, whether it is more or leſs intenſe; but the uſual proportion for a fine violet colour is two ounces of cochineal for each pound of ſilk. When the ſilk is dyed, it is waſhed at the river, twice beetled, dipped in a vat more or leſs ſtrong, in proportion to the depth of the violet ſhade, and then waſhed and dried with precautions ſimilar to thoſe which all colours require that are dyed in the vat. If the violet is to have greater ſtrength and beauty, it is uſual to paſs it through the archil bath, a practice which, though frequently abuſed, is not to be diſpenſed with for light ſhades, which would otherwiſe be too dull.

Purple.

389. When ſilk has been dyed with cochineal according to the above directions, only a very light ſhade is requiſite for purple; the ſhades which are deepeſt are dipped in a weak vat, while dipping them in cold water is ſufficient for ſuch as are lighter, the water having been incorporated with a ſmall quantity of the liquor of the vat, becauſe in the vat itſelf, however weak it might be, they would acquire too deep a tinge of blue. In this manner are the light ſhades of this colour, ſuch as gilly-flower, peach bloſſom, &c. produced by diminiſhing the quantity of cochineal.

Falſe violets.

390. There are various ways of imparting to ſilk what are denominated the falſe violets; but thoſe which are moſt frequently uſed, and poſſeſſed of greateſt beauty, are prepared with archil, the bath of which is, in point of ſtrength, to be ſuited to the colour required. Having been beetled at the river after ſcouring, the ſilk is turned in the bath on the ſkein ſticks; and when the colour is deemed ſufficiently deep, a pattern is tried in the vat, to aſcertain whether it takes the violet colour intended to be produced. If the ſhade is found to have acquired the proper depth, the ſilk is beetled at the river and dipped in the vat, in the ſame way as for the fine violet colours; and leſs either of the blue or of the archil colour is given, according as it is meant that the red or blue ſhade of the violet colour ſhould predominate.

Proceſs of Guhliche.

391. The proceſs recommended by Guhliche for communicating a violet colour to ſilk is the following. A pound of ſilk is to be ſoaked in a bath of two ounces of alum, and a like quantity of ſolution of tin, after having carefully poured off the ſediment formed in the mixture. The dye-bath is prepared with two ounces of cochineal reduced to powder with a dram of tartar, and the remaining part of the bath which has anſwered the purpoſe of a mordant, with the addition of a ſufficient quantity of water. When ſlightly boiled, ſuch a quantity of ſolution of indigo is added as may communicate

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* Berthollet, ii. 340.

cate to the bath a proper ſhade of violet; after which the ſilk is immerſed, and boiled till it has acquired the intended ſhade. It is then wrung, waſhed in a ſtream, and like every other delicate colour, muſt be dried in the ſhade. The light ſhades exhauſt the bath. But it ought to be obſerved, that this colour, which is ſaid to be a beautiful violet, poſſeſſes but little durability, and is apt to aſſume a reddiſh tinge, owing to the colour of the indigo fading firſt.

Another.

392. A violet colour may be imparted to ſilks, by immerſing them in water impregnated with verdigriſe, as a ſubſtitute for aluming, and next giving them a bath of logwood, in which they aſſume a blue colour, which is converted to a violet, either by the addition of alum to the bath, or by dipping them in a weaker or ſtronger ſolution of that ſubſtance, which communicates a red colour to the particles of logwood. This violet poſſeſſes but a ſmall degree of beauty, and little durability. But if alumed ſilk be immerſed in a bath of braſil-wood, and next in a bath of archil, after waſhing it at the river, a colour is obtained poſſeſſing a much higher degree of beauty and intenſity. The proceſs deſcribed above (385.), for dyeing wool, ſucceeds equally well, according to M. Decroizille, in communicating to ſilk a violet colour.

III. *Of Dyeing Cotton and Linen Violet.*

Common proceſs.

393. The moſt ordinary mode by which a violet colour is communicated to cotton and linen ſtuffs, is firſt to give them a blue ground in the vat, proportioned to the required ſhade, and to dry them. They are afterwards galled, in the proportion of three ounces of galls to a pound of ſtuff, and being left in this bath for 12 or 15 hours, are wrung out and dried again. They are next paſſed through a decoction of logwood, and when thoroughly ſoaked and taken out, the bath receives an addition of two drams of alum, and one of diſſolved verdigriſe for each pound of cotton or thread. The ſkeins are then dipped again on the ſkein ſticks, and turned for about 15 minutes, when they are taken out and aired. They are next immerſed in the bath for 15 minutes, taken out and wrung. To complete the proceſs, the vat employed is emptied; half of the decoction of logwood not formerly made uſe of is now poured in, with the addition of two drams of alum, and the thread is again dipped in it till it has acquired the ſhade propoſed, which muſt always regulate the ſtrength or weakneſs of the decoction of logwood. This colour reſiſts in a conſiderable degree the action of the air, but in point of permanency is much inferior to that which is obtained from the uſe of madder.

SECT. III. *Of the Mixture of Yellow and Red, or Orange.*

394. ORANGE is the uſual reſult of a compoſition of yellow and red colours, but an almoſt endleſs variety of ſhades may be produced, according as we vary the proportion of the ingredients, and the particular nature of the yellow made uſe of. It is ſometimes the practice of dyers to combine blue with yellow and red, the reſult of which is the colour denominated *olive*. Many varieties may be obtained from the uſe of weld, ſaw-wort, dyers-weed, and other yellows, and by employing tartar, alum, ſulphate of zinc, or ſulphate of copper in the bath, or in the preparation of the cloth.

I. *Of Dyeing Wool Orange.*

Orange by the ſcarlet proceſs.

395. By a proceſs exactly the ſame as that which is followed in communicating to ſtuffs a ſcarlet colour, an orange may be given to wool; but the quantity of red muſt be diminiſhed, and that of the yellow increaſed. If wool is dyed a red colour by means of madder, and afterwards yellow with weld, the reſulting compound is a cinnamon colour, and the moſt proper mordant in this caſe is a mixture of alum and tartar. The ſhades may be varied at pleaſure by ſubſtituting other yellow dye ſtuffs inſtead of weld, and by varying the proportions as circumſtances may require. Wool may receive a reddiſh yellow colour by paſſing it through a madder bath, after it has undergone the uſual proceſs for yellow, which has already been deſcribed. The ſtrength of the madder bath is always to be proportioned to the ſhade required. Braſil-wood is ſometimes employed with yellow ſubſtances, or mixed with cochineal and madder. Snuff, cheſnut, muſk, and other ſhades are produced, by ſubſtituting walnut-tree root, walnut peels or ſumach, for weld.

II. *Of Dyeing Silk, Orange, &c.*

Marone, &c.

396. Logwood, braſil-wood, and fuſtic, communicate to ſilk a marone and cinnamon colour, together with all the intermediate ſhades. The ſilk is ſcoured in the uſual manner, alumed, and a bath is prepared, by mixing together decoctions of the three different woods mentioned above, made ſeparately, varying the quantity of each according to the ſhade intended to be given; but the proportion of fuſtic ſhould be greateſt. The ſilk is turned in the bath on the ſkein ſticks, and when it is taken out, if the colour be uniform, it is wrung and again dipped in a ſecond bath of theſe three ingredients, according to the effect produced by the firſt, in order to obtain the ſhade required.

Olive,

397. The blue vat is not made uſe of, when an olive colour is to be communicated to ſilk. After being alumed, it is dipped in a bath of weld, which is made very ſtrong. To this is afterwards added the juice of logwood, with a ſmall quantity of ſolution of alkali when the ſilk is dipped. This converts it into green, and gives the olive colour. It is dipped again in this bath till it has acquired the ſhade wanted.

398. To communicate to it the colour known by the name of *rotten olive*, fuſtic and logwood are added to the bath after welding, without any alkali. If the colour wanted is to incline more to a red, the addition of logwood alone is ſufficient. A ſort of reddiſh olive may likewiſe be obtained, by dyeing the ſilk in a fuſtic bath, to which a greater or leſſer quantity has been added of ſulphate of iron and logwood.

III. *Of Dyeing Cotton and Linen Orange, &c.*

Cinnamon colour.

399. A cinnamon colour is communicated to thread and cotton, by commencing the proceſs for dyeing them with verdigriſe and weld; they are afterwards to be dipped in a ſolution of ſulphate of iron, denominated by the French *bain d'aſſurage*, and then wrung out and dried. As ſoon as they are dried, they are galled in the

Compound Colours.

the proportion of three ounces to the pound of ſtuff; then dried again, alumed as for red colours, and maddered. After being waſhed and dried, they are put into hot ſoap-ſuds, and turned till they have acquired a ſufficient degree of brightneſs. It is the practice of ſome dyers to add to the aluming a decoction of fuſtic.

Olive.

400. By boiling four parts of weld and one of potaſh in a ſufficient quantity of water, M. d'Apligny informs us, a fine olive colour is communicated to cotton and thread. Braſil wood which has been ſteeped for a night, is boiled ſeparately with a ſmall quantity of verdigriſe, and theſe ſolutions are mixed together in various proportions, according to the particular ſhade required. The thread or cotton is dipped in the compound ſolution in the uſual way.

Sect. IV. *Of the Mixture of Black with other Colours.*

Brown.

The compound colours which are obtained from the mixture of black and other colours, are brown, gray, drab, &c. according to the nature and proportions of the ſimple colours employed.

I. *Of Dyeing Woollen Stuffs Brown, Gray,* &c.

401. To give a browning to cloth, as ſoon as it has been dyed, it is dipped in a ſolution of ſulphate of iron, with the addition of an aſtringent, which makes a *black bath*. It is more common to mix a ſmall quantity of ſolution of iron with a bath of water, adding more till the dyed ſtuff dipped in it has received the intended ſhade. Sulphate of iron is ſometimes added to the dye bath; but by dipping the dyed ſtuff in a ſolution of this ſalt, the end is more eaſily attained. It is the uſual practice of M. Poerner to ſoak the ſtuff in a ſolution of ſulphate of iron, to which other ingredients are ſometimes added, and after having taken it out of the mordant, it is dipped in the dye bath.

Coffee colour.

402. In order to obtain coffee and damaſcene colours, with other ſhades of browns of the common dye, the firſt method is adopted; a colour more or leſs deep is communicated to them, according to the ſhade intended to be obtained by the browning; and a bath is made of galls, ſumach, and alder bark, with the addition of ſulphate of iron. Thoſe ſtuffs are firſt dipped to which the lighteſt ſhades are to be communicated, and when theſe are finiſhed, the browner ones are dipped; a quantity of ſulphate of iron being added for each operation, proportioned to the effect intended to be produced.

Gray.

403. Blueiſh grays are communicated to ſtuffs, according to Poerner, by the ſolution of indigo in ſulphuric acid, combined with a mixture of decoction of galls and ſulphate of iron, varying the ſhades according to the different quantities of theſe ingredients made uſe of. If to a bath compoſed of cochineal, fuſtic and galls, ſulphate of iron be added, other ſhades are obtained.

404. For marone, and ſuch other colours as bear a ſtrong reſemblance to it, ſaunders and galls are employed, and ſometimes a browning, with the addition of logwood. If dyed in the remains of a cochineal bath, theſe colours may be made to incline to a crimſon or purple, and the ſame effect is produced by adding a ſmall quantity of madder or cochineal to the bath. A little tartar gives a greater degree of brightneſs to the colour. With a mixture of galls, fuſtic, and logwood, and a greater or ſmaller quantity of madder, with the addition of a little alum, thoſe colours may be communicated to ſtuffs which are known by the name of *hazel*.

Compound Colours.

Hazel.

Puce colour.

405. M. Guhliche produces what is called a *puce* colour, by boiling for fifteen minutes a pound of woollen ſtuff with two ounces of alum, a certain proportion of vinegar and ſolution of iron, after which he leaves it in the mordant for twelve hours. He then makes a bath with the decoction of two ounces of white galls carefully poured off from the ſediment, and mixed with four ounces of madder, in which, when it grows hot, the ſtuff is immerſed, after being taken out of the mordant, allowing it to remain there, while the temperature is gradually increaſed, till the colour intended has been imparted to it; after which it is boiled for two minutes, waſhed, and dried in the ſun. The colour thus obtained poſſeſſes a great degree of durability. It is of a deeper brown by the omiſſion of the alum and vinegar in the mordant; and after theſe colours the lighter ſhades are dyed. Sumach may be employed as a ſubſtitute for half of the madder. Different brown colours poſſeſſing conſiderable permanency, may likewiſe be produced by the uſe of braſil and logwood, if more or leſs of a ſolution of iron be mixed with a decoction of theſe ſubſtances. The wool being previouſly alumed and galled, is dyed in it.

II. *Of Dyeing Silk with Mixtures of Black,* &c.

Purple violet.

406. M. Guhliche imparts to ſilk a purple violet without a blue ground, with a mixture of one part of galls diſſolved in white wine, with three parts of water, in which a pound of ſilk is macerated for twelve hours, ſoaked in a mordant made up of two ounces of alum, one ounce of ſolution of tin, and half an ounce of muriatic acid. After wringing the ſtuff, it is dyed in a bath compoſed of two ounces of cochineal and a ſmall quantity of ſolution of iron, till the intended ſhade has been communicated; and for ſhades which are lighter, the reſidua of theſe baths are ſufficient, either ſeparately or mixed together. Madder may be uſed in the ſame way, macerating a pound of ſilk in a ſolution of alum, mixed with an ounce of muriatic acid, and a quantity of ſolution of iron. When the ſtuff is wrung out, it is dyed in a bath made of eight ounces of madder. When deeper colours are wanted, ſome of the ſolution of galls in white wine is mixed with the madder and cochineal baths.

407. Silk may be dyed in a bath made of equal parts of braſil and logwood juice, adding a certain quantity of ſolution of iron, after the ſtuff has been ſoaked in a ſolution of two ounces of alum, and an ounce of muriatic acid. If ſolution of galls be added, the colour becomes deeper.

Brick colour.

Colours reſembling that of brick, may be produced, by immerſing ſilk in an anotta bath, after preparing it with a ſolution of galls mixed with a certain quantity of ſolution of iron. By the mixture of braſil, logwood, archil, and galls, and by a browning with ſulphate of iron, a number of different ſhades are produced; but the whole of them have more or leſs a tendency to fade, although their brightneſs is very pleaſing to the eye.

III. *Of Dyeing Silk with Mixtures of Black*, &c.

With black caſk.

408. A permanent violet colour may be given to thread and cotton, when ſcoured in the ordinary way, by preparing a mordant with two quarts of the bath of what is called the *black caſk*, and four quarts of water for each pound of ſtuff, which is made to boil, and the ſcum is removed which forms on the ſurface, till it wholly diſappears. The liquor is poured into a vat, and when warm, four ounces of ſulphate of copper and one ounce of nitre are diſſolved in it. The ſkeins are left to ſoak in it for ten or twelve hours, wrung out, and dried. If it is required to produce a deep violet colour, two ounces of verdigriſe muſt be added to the bath; and if the nitre be omitted, the colour becomes ſtill deeper by galling the thread more or leſs, prior to its being put into the mordant. If the nitre be increaſed, and the ſulphate of copper diminiſhed, the violet colour becomes more inclined to lilac. A number of various ſhades may be produced, by different modifications of the mordants employed.

Marone colour.

409. Cotton is galled, dipped, and wrought in the common way, when different ſhades of marone colour are wanted. To the bath employed muſt be added more or leſs of the liquor of the black caſk. The cotton is then waſhed in a bath mixed with verdigriſe, next welded, and dyed to a fuſtic bath, to which a ſolution of ſoda and alum is ſometimes added. When the cotton prepared in this manner has been thoroughly waſhed, it is next well maddered, dipped in a weak ſolution of ſulphate of copper, and laſt of all in ſoap ſuds.

Hazel.

410. For ſome hazel and ſnuff colours, a browning is communicated to ſtuffs by means of ſoot, after the welding and madder bath, to which galls and fuſtic have been added; ſometimes ſoot is mixed with this bath, and a browning is likewiſe imparted by means of a ſolution of ſulphate of iron; and for browning colours, walnut peels are ſometimes employed as a ſubſtitute for ſolutions of iron. For ſuch wools as are deſigned for the manufacture of tapeſtry, they are very advantageous, becauſe the colour is not changed into yellow by expoſure to the air, as is the caſe in browning which is imparted by means of iron; but remains a conſiderable time without any ſenſible change. The hue is indeed rather dull; but its goodneſs and very moderate price are ſufficient to recommend a more extenſive uſe of it for grave colours, which in common ſtuffs are ſometimes faſhionable.

Chap. III. *Of Calico-printing.*

Hiſtory.

411. This may be defined to be the art of communicating different colours to particular ſpots on the ſurface of cotton or linen cloth, while the reſt of the ſtuff retains its original white colour.

The wonderful and truly ingenious art of calico-printing ſeems to have been firſt known in India, and for more than two centuries before the commencement of the Chriſtian era. Although the Egyptians were well acquainted with this art in the days of Pliny, as he himſelf informs us, it can ſcarcely be doubted that they derived the knowledge of it from India, as that country rather than Egypt, produced the colouring and other materials for carrying it on. If we conſider its preſent improved ſtate, the elegance of different patterns, the beauty and durability of the colours which can now be imparted to cotton or linen ſtuffs, and the diſpatch with which the various operations of this art are conducted, we muſt be aſtoniſhed at the rapidity of its improvements, when we recollect that it has been known in Europe for little more than a century. Perhaps no other art has riſen to ſuch perfection in ſo ſhort a period.

412. Our readers will not expect that our account of this ſubject ſhould be tedious or elaborate, ſince the artiſt is preſumed to be already acquainted with the different proceſſes which are employed in calico-printing; and to ſuch as wiſh only for a general knowledge of the art, in a theoretical point of view, prolixity would be diſagreeable.

Nature of this art.

413. The art of calico-printing conſiſts in impregnating with a mordant, ſuch parts of cotton or linen ſtuffs as are to have particular colours communicated to them, and then dyeing them in the uſual manner with ſome colouring ſubſtance. Thoſe parts of the cloth only which receive the mordant are intimately united with the colouring matter, although the whole ſurface muſt be more or leſs tinged; but the parts which have not received the mordant are reſtored to their original brightneſs by means of waſhing, and afterwards bleaching it upon the graſs for ſome days, taking care to turn the wrong ſide towards the ſun. If red ſtripes are to be communicated to a piece of white cotton cloth, thoſe parts of its ſurface on which the ſtripes are intended to appear, are marked out by a pencil dipped in acetate of alumina; after which it is dyed with madder in the uſual way. When it is firſt taken out of the dyeing veſſel, its whole ſurface is red, but when it is waſhed and bleached, it reſumes its original whiteneſs, the ſtripes only excepted which, being impregnated with the acetate of alumina, remain red. By a ſimilar proceſs may yellow or any other ſtripes be fixed upon cotton or linen, by the ſubſtitution of quercitron bark, weld, &c. in the room of madder.

To communicate different colours.

414. When different parts of the cloth are to receive different coloured ſtripes at the ſame time, different mordants muſt be employed. If ſtripes are delineated on its ſurface with the acetates of alumina and iron, and if it be then dyed with madder in the ordinary way, it will, after being waſhed and bleached as formerly directed, exhibit ſtripes of a red and brown colour. If the ſame mordants are employed, but quercitron bark uſed inſtead of madder, the ſtripes will then be *yellow*, and *olive* or *drab*.

Uſual mordants.

415. The mordants known by the names of acetate of alumina and acetate of iron, which are made uſe of in calico-printing, may either be applied to ſtuffs with a pencil, as already mentioned, or ſtill more expeditiouſly by means of blocks, on which the intended patterns are cut. Being deſigned only for particular parts of the ſurface of the cloth, great caution is neceſſary to prevent them from ſpreading to any part of it which is to remain white, and to prevent their interference when the application of more than one is required. Such a degree of conſiſtence muſt of conſequence be given to the mordants employed, as will prevent this diſagreeable effect, which cannot fail to deſtroy the beauty

and elegance of the print. If blocks are to be made uſe of, the mordants may be brought to a proper conſiſtence by means of ſtarch; but gum arabic muſt be mixed with them, when the pencil is to be employed. The thickneſs ſhould not exceed what is abſolutely neceſſary to prevent the mordants from ſpreading; becauſe, if carried too far, the cotton is frequently not ſaturated with the mordant, in conſequence of which the dye is but imperfectly communicated.

416. To diſtinguiſh thoſe parts of the cloth which are impregnated with mordants, it is a common practice to give the mordants ſome particular tinge by which they may be known; and for this purpoſe printers commonly make uſe of the decoction of braſil wood. Dr Bancroft objects to this practice, becauſe he is of opinion that the proceſs of dyeing is impeded by the colouring matter of braſil wood. The affinity of the dye ſtuff for the mordant diſplaces the colouring matter of the braſil wood; and without ſuch affinity it would be impoſſible to ſtrike the colour. Some of the dye-ſtuff to be employed afterwards is recommended by Dr Bancroft for colouring the mordant, who prohibits the uſe of a larger quantity than what is ſufficient to render it diſtinguiſhable when an application of it is made to the cloth. Should too large a quantity be united with the mordant, a conſiderable proportion of the latter would be combined with colouring matter, by which means its affinity for the cloth would be diminiſhed, and therefore a permanent colour could not be expected to reſult from ſuch a partial combination.

Application of the mordant.

Cloth muſt be dried,

417. It is neceſſary to dry the cloth completely after the application of the mordants, for which purpoſe artificial heat may be employed, which has a tendency to promote the ſeparation of the acetous acid from its baſe, and aſſiſt its evaporation, and thus the combination of the mordant with the cloth will be facilitated.

and then waſhed.

418. When the cloth is thoroughly dried, it is cuſtomary to waſh it with warm water and cow-dung, till every particle of the ſtarch or gum arabic which had been employed to give a proper conſiſtence to the mordants, and thoſe parts of them which do not combine with the cloth, are entirely removed. The looſe particles of the mordant are entangled by means of the cow-dung, and prevented from being attached to thoſe parts of the cloth which are to remain white. After this, it muſt be completely rinſed in pure water.

Colouring matters employed.

419. Indigo, madder, quercitron bark, and weld, are the chief dying ingredients made uſe of by calico-printers; but the laſt of theſe is ſeldom uſed by the printers of this country, except for the purpoſe of communicating yellows of a delicate greeniſh ſhade. Quercitron bark, on account of its inferior price, and capacity of imparting colours equally good, as well as requiring a leſs degree of heat, is employed as a ſubſtitute. It is uſual to apply indigo at once, either by means of the block or pencil, becauſe it requires not the intervention of a mordant to fix it. This preparation is made by boiling together indigo, potaſh reduced to the cauſtic ſtate by means of quicklime, and orpiment; afterwards thickening the ſolution with gum. Dr Bancroft recommends the uſe of coarſe brown ſugar as a ſubſtitute for orpiment, which operates as powerfully in the decompoſition of the indigo, and in promoting its ſolubility, anſwering at the ſame time all the purpoſes of gum.

Dyeing proceſs.

420. When the cloth is thoroughly cleanſed after it has been impregnated with the mordant, the dyeing proceſs is conducted in the uſual manner. As the whole of it receives a tinge of the dye, it muſt be completely waſhed and bleached for ſome days on the graſs, as formerly mentioned, by which means the colour is entirely removed from thoſe parts of the cotton not impregnated with the mordant, while all the other parts of it retain the colouring matter as powerfully as at firſt.

Nankeen yellow, &c.

421. One of the moſt common colours imparted to cotton prints is a ſpecies of nankeen yellow of different ſhades, and for the moſt part in ſtripes or ſpots. It is produced by means of a block on which is cut the intended pattern, rubbed over with acetate of iron brought to a proper conſiſtence with gum or ſtarch, and applied to the cotton; which, being dried and cleanſed in the ordinary way, is immerſed in a ley of potaſh. It is proper to obſerve, that the quantity of acetate of iron muſt be proportioned to the particular ſhade required.

Yellow.

422. In order to produce a yellow colour, the block is rubbed over with acetate of alumina; and the cloth, after being impregnated with this mordant, is dyed with quercitron bark in the common manner, and then bleached.

Red.

423. If madder be ſubſtituted for the quercitron bark, a red colour is given to cotton by the ſame proceſs.

Blue.

424. To communicate to ſtuffs the fine light blue colours which we frequently behold upon cotton, the block is rubbed over with a compoſition conſiſting partly of wax, by means of which all thoſe parts of its ſurface are to remain white. It is next dyed in a cold vat of indigo, and when it is dried, the wax compoſition may be removed by the uſe of hot water.

Lilac, &c.

425. Lilac and blackiſh brown colours are communicated by acetate of iron, proportioning the quantity to the particular ſhade required, and adding a little ſumach for ſuch ſhades as are to be very deep. The cotton is then dyed with madder and bleached in the uſual manner. Dove colour and drab are produced by means of acetate of iron and quercitron bark.

How to apply different colours.

426. When a variety of different colours are to be made on the ſame print, a greater number of operations are unavoidably neceſſary. Upon each of the blocks to be employed is cut that particular part of the pattern which is to have one appropriate colour; and when theſe blocks are rubbed over with their reſpective mordants and thus applied to the cloth, the dyeing proceſs is afterwards conducted in the ordinary manner. If, for example, three different blocks are to be made uſe of, the firſt rubbed over with acetate of alumina brought to a proper conſiſtence, the ſecond with acetate of iron, and the third with a compoſition of theſe two, the colours reſulting, after the dyeing and bleaching proceſſes are finiſhed, will be the following.

Acetate of alumina	yellow,
iron	olive, drab, dove.
From the compound	olive green, olive.

It is proper to obſerve, that theſe are the reſults when quercitron bark is employed; but by the ſubſtitution of madder the following colours will be obtained.

Acetate of alumina	red,
iron	brown, black.
From the compound	purple.

When it is required to produce at the ſame time both thoſe colours which are imparted by madder, and likewiſe by the uſe of quercitron bark, mordants are firſt applied for one part of the pattern, after which the cotton is dyed in a bath of madder, and then bleached. The reſt of the mordants are then applied in a ſimilar manner, after which the cotton is dyed with the quercitron bark, and bleached as before. The colours which the madder communicates are very little affected by the ſecond dyeing, becauſe the mordants by which their permanency is ſecured, are previouſly ſaturated. A new mordant may be applied to ſome of the colours reſulting from the uſe of madder, by which means they receive a new durable colour from the bark. And by means of the indigo liquor other new colours may ſtill be communicated after the laſt bleaching.

Variety of colours by different proceſſes.

427. The following colours may be communicated to cotton, by means of the different proceſſes which have been deſcribed.

Madder Dye.

Acetate of alumina	red,
iron	brown, black,
Ditto diluted	lilac,
Mixture of the two	purple.

Bark Dye.

Acetate of alumina	yellow,
iron	dove, drab,
Lilac and acetate of alumina	olive,
Red and acetate of alumina	orange.

Indigo Dye.

Indigo	blue,
Indigo and yellow	green.

Thus may twelve different colours be communicated to the ſame print by theſe different proceſſes.

Colours for penciling.

428. If durable colours could be directly applied to cotton by means of the block or pencil, without the help of mordants, nothing could be conceived more ſimple than the art of calico-printing; but with the ſingle exception of indigo, the communicating of permanent colours requires the proceſs of dyeing. Yellow, indeed, which is a compound colour, and ſome others, may be communicated to cotton at once, by mixing together an infuſion of quercitron bark and acetate of alumina, while the ſame mordant with a decoction of madder, imparts to it a red colour; but thoſe which are produced in this way are far from being durable, ſince they are deſtroyed by waſhing, and ſometimes even by expoſure to the air.

Compoſition for yellow colour.

429. But as it is not always practicable for calico-printers to avoid the application of colours in this manner, every endeavour to give them a greater degree of permanency becomes an object of importance. The following compoſition has been recommended for a yellow printing colour. Three pounds of alum, and three ounces of pure chalk are to be diſſolved in a gallon of hot water, to which are to be added two pounds of acetate of lead. This mixture is to be occaſionally ſtirred for 24 or 36 hours, after which it is to remain at reſt during 12 hours. The clear liquor is then to be poured off, and as much more hot water added to the reſiduum, as will, after being ſtirred and allowed to ſettle, amount to three quarts when added to the firſt quantity. Into a tinned copper veſſel put ſix pounds, or at moſt a quantity not exceeding eight pounds, of quercitron bark ſufficiently ground, and boil it for an hour in four or five gallons of clean ſoft water, adding afterwards a little more water if the bark is not properly covered. When the liquor is thoroughly boiled, let it be removed from the fire, and left to ſettle for half an hour, when the clear decoction is to be poured off through a fine ſieve. Six quarts more of pure water are then to be put upon the ſame bark, and boiled for a quarter of an hour, being previouſly well ſtirred. When it has ſtood a ſufficient time to ſettle, the clear liquor is to be ſtrained off, and being mixed with the former, both are put into a ſhallow wide veſſel to be evaporated by boiling, till the whole, in addition to the mordant already mentioned, and the gum or paſte for bringing it to a proper conſiſtence, does not exceed three gallons. It will be proper not to add the three quarts of aluminous mordant till the decoction has been cooled down almoſt to the natural heat of blood. Let gum arabic or gum ſenegal be taken for thickening, if the pencil is to be uſed, and ſtarch or flour when blocks are to be employed.

For bright yellow.

430. If a pound of murio-ſulphate of tin be uſed as a ſubſtitute for the aluminous mordant in the compoſition deſcribed above, a mixture will be produced which is capable of imparting to cotton a very bright yellow, and conſiderably permanent.

Cinnamon colour.

431. A cinnamon colour poſſeſſed alſo of a ſufficient degree of permanency may be given to cotton, by means of a mixture of ſulphate of tin and a decoction of the quercitron bark.

Green.

432. If the decoctions of this bark and of logwood are boiled together, and proper quantities of ſulphate of copper and verdigriſe added to them, together with a ſmall proportion of carbonate of potaſh, there reſults a compound which communicates to cotton a green colour. Although the expectations of Dr Bancroft were not fully anſwered by the trials which he made of this ſubſtance, he deemed his ſucceſs ſufficient to encourage him to a farther inveſtigation of it.

Drab and olive.

433. A permanent drab colour may be given to cotton by means of acetate of iron mixed with a decoction of quercitron bark, and reduced to a proper conſiſtence. This mixture will alſo produce an olive, if added to the olive colouring liquor already mentioned; and the colours may be made ſtill more permanent; if a ſolution of iron in diluted nitric or muriatic acid be uſed as a ſubſtitute for iron liquor. They ought, however, to be uſed ſparingly and with caution, that the texture of the cotton or linen to which they are applied may not be injured.

Colours from different mordants and the quercitron bark.

434. Dr Bancroft made a number of experiments with the decoction of quercitron bark, to aſcertain its effects when combined with different metallic ſalts as mordants. The ſulphate, nitrate, and muriate of zinc, with this decoction, yielded browniſh yellow colours of different ſhades; but none of them were found ſufficiently permanent when they were applied topically to linen or cotton. Mercury in the different acids produced

Indian Method of Dyeing Red.

duced with the decoction of bark different ſhades of brown or yellowiſh brown colours; but they did not prove more durable than the former. The nitro-muriate of platina with a proper proportion of decoction of quercitron bark, afforded, when topically applied to linen or cotton, ſtrong full-bodied ſnuff colours, which were found ſufficiently permanent, and capable of reſiſting the action of acids, and of the ſun and air. Nitrate of ſilver with a decoction of the bark, when applied topically to linen or cotton, produced ſtrong dark brown and cinnamon colours of conſiderable durability. Nitrate of lead with the ſame decoction gave by topical application a drab colour which was not leſs durable than the former. Nitrate of biſmuth produced with the decoction of bark a very full and ſtrong browniſh yellow. This colour, however, is attended with the inconvenience of becoming almoſt black when expoſed to the action of the alkaline ſulphurets, ſulphurated hydrogen gas, or even by the action of common ſoap. Muriate of biſmuth with the decoction gives a drab colour; ſulphate of the ſame metal affords a yellow; but theſe colours when applied to cotton or linen are not durable. Nitro-muriate of antimony produced with the decoction of bark ſomething of a ſnuff colour, which applied to linen and cotton poſſeſſes ſome degree of durability. Nitrate and muriate of cobalt with the quercitron bark gave different ſhades of brown; but theſe colours were extremely fugitive; they ſoon faded by expoſure to the ſun and air.

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Woollen ſtuffs printed.

435. The art of calico-printing has been hitherto almoſt ſolely limited to linens and cottons. Many colouring matters have ſuch an affinity for theſe ſtuffs that they readily enter into combination with them at the ordinary temperature of the atmoſphere. This is alſo the caſe with ſilk, ſo that colouring matters might be applied topically to the latter by means of ſimilar operations as to linen and cotton. Attempts, however, have been made to extend the proceſs of topical dyeing or printing to woollen ſtuffs, and particularly thoſe kinds known by the name of kerſeymeres, which are employed after being prepared in this way for waiſtcoat patterns. When it is recollected that woollen ſtuffs when they are to be dyed generally muſt be expoſed to a conſiderable degree of heat, it is eaſy to conceive that it will be difficult to communicate ſpots or figures by printing to woollen ſtuffs. The means by which this difficulty is obviated in thoſe manufactories where this operation is conducted have been hitherto kept ſecret. The preparation of colouring matters, whether ſuch as may be employed ſimply or require the uſe of mordants to fix them, will be eaſily underſtood from what we have already fully detailed in the courſe of this treatiſe. The application of the colours is made in the uſual way; and it is ſaid that, after the woollen ſtuffs are printed, they are wrapped up in two or three folds of thick paper, to prevent the acceſs of moiſture which might cauſe the colours to run, and expoſed to the ſteam of boiling water for ſuch a length of time as may be ſuppoſed neceſſary for the colouring matter to combine with the ſtuffs †.

APPENDIX.

After that part of the preceding treatiſe to which it properly belongs, was printed off, the following account of the Indian method of dyeing cotton cloth and cotton thread a red colour came under our notice. It was communicated to the ſociety for the encouragement of arts, &c. by Mr Maclachlan of Calcutta. The inſertion of it may perhaps excite the curioſity of ſome of our countrymen to farther inquiries into the ſtate of this as well as of other arts in India, where, from being long known and practiſed, many of them have arrived at a high degree of ſimplicity and perfection.

Directions for dyeing a bright Red, four yards of three-fourths broad Cotton Cloth.

1ſt. The cloth is to be well waſhed and dried, for the purpoſe of clearing it of lime and congee, or ſtarch, generally uſed in India for bleaching and dreſſing cloths; then put into an earthen veſſel, containing twelve ounces of chaya or red dye root, with a gallon of water, and allow it to boil a ſhort time over the fire.

2d. The cloth being taken out, waſhed in clean water, and dried in the ſun, is again put into a pot with one ounce of myrobalans, or galls coarſely powdered, and a gallon of clear water, and allowed to boil to one half: when cool, add to the mixture a quarter of a pint of buffalo's milk. The cloth being fully ſoaked in this, take it out, and dry it in the ſun.

3d. Waſh the cloth again in clear cold water, and dry it in the ſun; then immerſe it into a gallon of water, a quarter of a pint of buffalo's milk, and a quarter of an ounce of the powdered galls. Soak well in this mixture, and dry in the ſun. The cloth, at this ſtage of the proceſs, feeling rough and hard, is to be rolled up and and beetled till it becomes ſoft.

4th. Infuſe into ſix quarts of cold water, ſix ounces of red wood ſhavings, and allow it to remain ſo two days. On the third day boil it down to two-thirds the quantity, when the liquor will appear of a good bright red colour. To every quart of this, before it cools, add a quarter of an ounce of powdered alum; ſoak in it your cloth twice over, drying it between each time in the ſhade.

5th. After three days waſh in clean water, and half dry in the ſun; then immerſe the cloth into five gallons of water, at about the temperature of 120° of Fahrenheit, adding 50 ounces of powdered chaya, and allowing the whole to boil for three hours; take the pot off the fire, but let the cloth remain in it until the liquor is perfectly cool; then wring it gently, and hang it up in the ſun to dry.

6th. Mix intimately together, by hand, about a pint meaſure of freſh ſheep's dung, with a gallon of cold water, in which ſoak the cloth thoroughly, and immediately take it out, and dry it in the ſun.

7th. Waſh the cloth well in clean water, and ſpread it out in the ſun on a ſand-bank (which in India is univerſally preferred to a graſs-plat) for ſix hours, ſprinkling

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† Bancroft, 189.

Indian Method of Dyeing Red.

ling it from time to time, as it dries, with clean water, for the purpoſe of finiſhing and perfecting the colour, which will be of a very fine bright red.

Directions for dyeing of a beautiful red, eight ounces of Cotton Thread.

1ſt. Put one gallon and a half, by meaſure, of ſapwood aſhes, into an earthen pot, with three gallons of water, and allow the mixture to remain twenty-four hours to perfect it for uſe.

2d. Put the following articles into an earthen pot, viz. Three quarters of a pint of Gingelly oil; one pint, by meaſure, of ſheep's dung, intimately mixed by hand in water; two pints of the above ley.—After mixing theſe ingredients well, pour the mixture gradually upon the thread into another veſſel, wetting it only as the thread, by being ſqueezed and rolled about by the hand, imbibes it, continuing to do ſo until the whole is completely ſoaked up, and allow the thread to remain in this ſtate until next day.

3d. Take it up, and put it in the ſun to dry; then take a pint and a half of aſh-ley, in which ſqueeze and roll the thread well, and allow it to remain till next day.

4th. Squeeze and roll it in a like quantity of aſh-ley, and put it in the ſun to dry; when dry, ſqueeze and roll it again in the ley, and allow it to remain till next day.

5th. Let the ſame proceſs be repeated three or four times, and intermit till next day.

6th. Ley the thread once, as the day before, and, when well dried in the ſun, prepare the following liquor: One gill of Gingelly oil; one pint and a half of aſh-ley.—In this ſqueeze and roll the thread well, and leave it ſo till next day.

7th. Repeat the proceſs of yeſterday, and dry the thread in the ſun.

8th. The ſame proceſs to be repeated.

9th. Firſt repeat the aſh-ley proceſs three or four times, as under the operations 3, 4, and 5, and then prepare the following mixture: One pint of ſheep-dung water; one gill of Gingelly oil; one pint and a half of aſh-ley.—In this ſqueeze and roll the thread well, and dry it in the ſun.

10th. Repeat the ſame proceſs.
11th. Do. Do.
12th. Do. Do.
13th. Do. Do.
14th. Do. Do.

15th. Waſh the thread in clean water, and ſqueeze and roll it in a cloth until almoſt dry; then put it into a veſſel containing a gill of powdered chaya root, one pint by meaſure of caſhan leaves, and ten pints of clear water; in this liquor ſqueeze and roll it about well, and allow it to remain ſo till next day.

16th. Wring the thread, and dry it in the ſun, and repeat again the whole of the 15th proceſs, leaving the thread to ſteep.

17th. Wring it well, dry it in the ſun, and repeat the ſame proceſs as the day before.

18th. Do. Do.
19th. Do. Do.

20th. Wring and dry it in the ſun, and with the like quantity of chaya root in ten pints of water; boil the thread for three hours, and allow it to remain in the infuſion until cold.

21ſt. Waſh the thread well in clear water, dry it in the ſun, and the whole proceſs is completed.

INDEX.

DYNAMICS.

Definition.

1. DYNAMICS is that branch of phyſico-mathematical ſcience which includes the abſtract doctrine of *moving forces*; that is, the neceſſary reſults of the relations of our thoughts concerning motion, the immediate cauſes of motion, and its changes.

Idea of motion.

2. Motion and its general properties are the firſt and principal object of mechanical philoſophy. This ſcience indeed preſuppoſes the exiſtence of motion; and we may conſider it as univerſally admitted and recogniſed. With regard to the nature of motion, however, philoſophers are greatly divided in opinion. The moſt obvious and ſimpleſt conception of motion is the ſucceſſive application of the moving body to the different parts of indefinite ſpace, which are conſidered as the place of the body. This idea of motion ſuppoſes a ſpace whoſe parts are penetrable and immoveable; a doctrine directly contrary to that of the followers of Des Cartes, who regarded extenſion and matter as one and the ſame thing. To have a diſtinct idea of motion, it ſeems requiſite to conceive two kinds of extenſion; the one, which is conſidered as impenetrable, and which conſtitutes what we properly call *matter* or *body;* the other, which being ſimply conſidered as extended, without taking any other property into account, is the meaſure of the diſtance of one body from another; and whoſe parts being ſuppoſed fixed and immoveable, enable us to judge of the reſt or motion of bodies. We may therefore conceive bodies to be placed in indefinite ſpace, whether real or ſuppoſed; and motion as a change in the ſtate or condition of a body from one part of ſpace to another. We muſt indeed conſider motion as a ſtate or condition of exiſtence of a body, which would remain till it is changed by ſome cauſe; otherwiſe we could not have any idea of motion in the abſtract. From the changes which we obſerve, we infer agency in nature; and in theſe changes we are to diſcover what we know of their cauſes.

Idea of ſpace.

3. In mechanical diſquiſitions, the ſimpleſt, and at the ſame time the moſt uſual conception of ſpace, is mere extenſion. We think only of the diſtance between two places. The path along which any body moves in paſſing from one place or point in ſpace to another, is ſaid figuratively to be the path deſcribed by that body. Space is conſidered by the geometer not only as having length but alſo breadth. In this caſe it is called a *ſurface.* But to have a more complete notion of the capaciouſneſs of any portion of ſpace, thickneſs, as well as length and breadth, is taken into conſideration. This is called a ſolid ſpace. By this, however, is meant only the ſuſceptibility of meaſure in three ways, or extenſion of three dimenſions. The adjacent parts or portions of ſpace are diſtinguiſhed from each other by their mutual boundaries. Contiguous portions of a line are ſeparated by points; contiguous portions of a ſurface are ſeparated by lines; and contiguous portions of a ſolid are ſeparated by ſurfaces. The boundaries of any portions of ſpace are not to be conſidered as parts of the contiguous portions. They muſt be conceived as common to both; as the places where one portion ends and another begins. Space cannot be ſaid to have any bounds or limits; it is therefore ſaid to be infinite or unbounded.

Relative and abſolute ſpace.

4. Any portion of ſpace may be conſidered in relation to its place or ſituation among other portions of ſpace. This portion of ſpace which is occupied by any body has been called the *relative place* of that body. But this portion of ſpace may be conſidered as a determinate portion of infinite ſpace; and this portion of infinite ſpace occupied by any body has been called the *abſolute place* of that body. Space, it is obvious, taken in this meaning, is immoveable; for it cannot be conceived that this identical portion of ſpace can be removed from one place to another. The body which occupies that ſpace may be removed, but the ſpace remains. We have no perception of the abſolute ſpace of any object. This may be illuſtrated by the motion of the earth or that of a ſhip. A perſon in the cabin of a ſhip does not conſider the table as changing its place while it remains fixed to the ſame ſpot on the deck. While a mountain is obſerved to retain the ſame ſituation among other objects, few perſons think that it changes its place.

Idea of time.

5. The idea of time is acquired by means of the power of memory in obſerving the ſucceſſion of events. We conceive time as unbounded, continuous, homogeneous, unchangeable in the order of its parts, and infinitely diviſible. It is conceived as a proper quantity made up of its own parts, and meaſured by them. But as the relation of the parts of time is unknown, the only means which we can employ to diſcover this relation, is to find out ſome other relation which is more obvious and better known, to which it may be compared. We ſhall then have diſcovered the ſimpleſt meaſure of time, if we compare in the ſimpleſt manner poſſible the relation of the parts of time with thoſe relations which are moſt familiar. Hence it follows, that uniform motion is the ſimpleſt meaſure of time. For, on the one hand, the relation of the parts of a right line is that which is moſt eaſily conceived; and, on the other hand, there are no relations more ſuſceptible of compariſon with each other than equal relations. Now, in uniform motion, the relation of the parts of time is equal to that of the correſponding parts of the line deſcribed. Uniform motion then gives us at once, both the means of comparing the relation of the parts of time with that which is moſt obvious to our ſenſes, and alſo of making this compariſon in the ſimpleſt manner. In uniform motion, then, we find the ſimpleſt meaſure of time. It may be added, that the meaſure of time by uniform motion, is, independent of its ſimplicity, that which is the moſt natural to think of employing. Indeed as there is no relation with which we are acquainted more accurate than that of the parts of ſpace; and, as in general, a motion, the law of which is given, would lead us to diſcover the relation of the parts of time, by the known analogy with that of the parts of ſpace paſſed over, it is evident that ſuch a motion would be the moſt accurate meaſure of time,

and that which ought to be employed in preference to every other. In the actual meaſurement of time, ſome event which is imagined always to require an equal time for its accompliſhment is ſelected; and this time is employed as a unit of time or duration, in the ſame way as a foot rule is employed as a meaſure of extenſion. During any obſerved operation, as often as this event is accompliſhed, ſo often is it ſuppoſed that the time of the operation contains this unit. While a heavy body falls 16 feet, a pendulum, $39\frac{1}{8}$ inches long, makes one vibration; but it makes three vibrations, while the ſame body falls 144 feet. It is therefore ſaid that the time of a body falling 144 feet, is thrice as great as the time of falling 16 feet.

Analogy between the affections of time and ſpace.

6. Between the affections of time and ſpace, there is an obvious analogy; and hence in moſt languages the ſame words are employed to expreſs the affections of both. Thus it is that time may be repreſented by lines and meaſured by motion; ſince uniform motion is the ſimpleſt ſucceſſion of events that can be conceived. In the order of ſituation, all things are placed in ſpace. In the order of ſucceſſion all events happen in time.

Having made theſe preliminary obſervations, we propoſe to divide the following treatiſe into two parts. In the firſt, we ſhall conſider motion in general. In the ſecond, we ſhall treat of *moving forces*, or of *dynamics*.

PART I. OF MOTION.

BEFORE we enter on the conſideration of the different kinds of motion, it may be neceſſary to notice ſome general circumſtances regarding it.

No motion inſtantaneous.

7. It is impoſſible to conceive that any motion can be inſtantaneous. A moving body, in paſſing from the beginning to the end of its path, muſt paſs through all the intermediate points. Now to ſuppoſe the motion along even the moſt minute portions of the ſpace paſſed through inſtantaneous, is to ſuppoſe that the moving body is in every intervening point at the ſame inſtant; which is impoſſible.

Abſolute and relative motion.

8. Relative motion is the change of ſituation with regard to other objects. Abſolute motion is the change of abſolute place. Theſe two motions, it may be obſerved, may not only be different, but even contrary to each other. From the relative motions of things which are the differences of their abſolute motions, we cannot find out what are the abſolute motions. It is often a ſubject of elaborate and intricate inveſtigation to diſcover and determine the abſolute motions, by means of obſerving the relative motions.

Quantity of motion.

9. The affections or circumſtances of motion are various with regard to its quantity and its direction. That affection of motion by which the quantity is determined, is called *velocity*. The length of the line, which is uniformly deſcribed or paſſed over during ſome given portion or unit of time, is the proper meaſure of this velocity. When a ſhip ſails ſix miles per hour, ſhe deſcribes a length of line equal to ſix miles in the ſpace of a given portion or unit of time, namely, the hour; and thus the velocity of the ſhip is ſaid to be aſcertained.

Direction of motion.

10. Another affection or circumſtance of motion is its *direction*. This is the poſition of the ſtraight line along which the motion is performed. The ſtraight line which a body deſcribes or tends to deſcribe is called its direction. The motion is ſaid to be in the direction AB fig. 1. when the body moved paſſes along the line AB from A to B. In common language, it is not unuſual to expreſs the direction of motion in a manner quite the reverſe of this. We have an inſtance of this kind in ſpeaking of the direction of the winds. A current of air or wind which moves eaſtward is ſaid to be a weſterly wind, deriving its name from the point or quarter from which it proceeds, not as in other caſes, and in ſtrict expreſſion, from the point to which it is directed.

Rectilineal motion.

11. Motions are of different kinds. They are either rectilineal, deflected, or curvilineal. In a rectilineal motion the direction remains unchanged during the whole time that the motion is continued, as when a body moves from A to B fig. 1. In a deflected motion it is performed along two contiguous ſtraight lines in ſucceſſion. Thus if a body moves from A to B fig. 2. and at the point B its direction is changed from that of AD to BC; this change has been called *deflection*, the quantity of which may be meaſured either by the angle DBC, or by a line DC drawn from the point D to which the body would have arrived in the ſame time, if its motion had remained unchanged, in which it has actually reached the point C. When a body in moving along deſcribes the ſides of a polygon, the deflections are repeated, with the intervention of undeflected motions. In curvilineal motion the deviation and deflection are ſuppoſed to be continual. Continual deflection therefore conſtitutes curvilineal motion. Let the motion be performed along a curve line ABCDE (fig. 3.), the direction is continually changing. When the body is in the point C the direction is that of the tangent CF; becauſe this direction alone lies between any pair of polygonal directions, ſuch as CE and C*a*, or CB and CD, however near the points A and E, or B and D, are taken to the point C.

Deflected.

Curvilineal.

Diviſion of motions.

12. Motions have been divided into *uniform* motions, *variable*, *compound*, and *curvilineal*. Theſe we ſhall conſider ſeparately in the following ſections.

SECT. I. *Of Uniform Motion.*

Importance of fixed characters of uniform motion.

13. It is of great importance in mechanical diſquiſitions, to have the characters of uniform or unchanged motion fixed. For in our conceptions of motion in general, in which we do not turn the attention to its alterations, the motion is ſuppoſed to be equable and rectilineal. By the deviations from ſuch motion only can we determine the marks and meaſures of all changes; and hence alſo we are to obtain the meaſures of all changing cauſes, or in other words of the mechanical powers of nature.

PROPOSITION I.

14. *In uniform motions, the velocities are in the proportions of the ſpaces deſcribed in the ſame or in equal times;*

times; or as it is ſometimes expreſſed, *The velocities are proportional to the ſpaces deſcribed in equal times.*

The ſpaces deſcribed are the meaſures of the velocities, and things are proportional to their meaſures. Let the ſpaces deſcribed in the time T, be repreſented by S and s, and let the velocities be repreſented by V and v. We have the analogy $V : v = S : s$. Or, as it may be expreſſed by the proportional equation $v \doteqdot s$.

Prop. II.

15. *In uniform motions with equal velocities, the times are in the proportion of the ſpaces deſcribed during their currency.* Or, as it is alſo expreſſed, *The times are proportional to the ſpaces deſcribed with equal velocities.*

For in uniform motions, equal ſpaces are deſcribed in equal times. The ſucceſſive portions of time therefore are equal, in which equal ſpaces are deſcribed in ſucceſſion; and the ſums of the equal times muſt be proportional to the correſponding ſums of equal ſpaces. In all caſes, therefore, which are ſuſceptible of being repreſented by numbers, this propoſition is evident. And it may be extended to all other caſes, in a way ſimilar to that in which Euclid has demonſtrated that triangles of equal baſes are in the proportion of their baſes.

16. As proportion can only take place between quantities of the ſame kind, all that is to be underſtood by the expreſſions in the above propoſitions, which are far from being accurate, is, that the proportions of the velocities and the times are the ſame with the proportions of the ſpaces. For as ſpace and time are quantities of a different nature, it is evident that we cannot divide ſpace by time. Thus when it is ſaid that *the velocities are as the ſpaces divided by the times*, it is an abridged mode of expreſſion, which ſignifies that the velocities are as the relations of the ſpaces to the ſame common meaſure, divided by the relations of the times to the ſame meaſure. Thus, for example, if we take a foot for the meaſure of the ſpaces, and a minute for the meaſure of the times, the velocities of two bodies which move uniformly, are to each other as the number of feet deſcribed, divided by the number of minutes which the bodies require to deſcribe the portion of ſpace paſſed through, and not as the feet divided by the minutes.

Uniform motion a meaſure of time.

17. Hence it is that uniform motion is univerſally employed as a meaſure of time. But it is often difficult to find out whether the motion which is propoſed for the meaſure of time be perfectly uniform. What then are the means to aſcertain this? To this it may be anſwered that there is no motion which is not uniform, the law of which we can determine exactly; ſo that this difficulty only proves that we cannot aſcertain the relation of the parts of time with mathematical preciſion; but it does not follow that uniform motion from its nature may not be the firſt and ſimpleſt meaſure. And having no ſtrictly accurate meaſure of time, we endeavour to diſcover the meaſure which comes neareſt in the motions which approach neareſt to uniformity.

Method of aſcertaining when a motion is nearly uniform.

18. There are three ways by which it may be aſcertained that a motion is nearly uniform. 1. When the moving body deſcribes equal ſpaces in times which we judge to be equal; and we can determine that the times are equal, after having obſerved from repeated experience that ſimilar events take place in the ſame times. Thus we conclude that the times which the ſame clepſydra requires to be emptied are equal; ſo alſo the times in which the ſame quantity of ſand runs in the ſandglaſs; the times in which the ſhadow moves over the ſame ſpace on the ſundial; the times of the ſame number of vibrations of a pendulum of the ſame length; and the times of the revolution of the heavenly bodies through the ſame ſpaces are equal. If then it is found by obſervation that a body during the ſame times paſſes over equal ſpaces, we conclude that the motion is uniform. 2. Another method of aſcertaining how far any motion is uniform, is when the effect of the accelerating or retarding cauſe, if ſuch operate, is imperceptible. It is by combining theſe two methods that we conclude the motion of the earth round its axis to be uniform; and this inference is not only not oppoſed by any of the celeſtial phenomena, but ſeems to be in perfect accord with them. 3. By a third method of determining the uniformity of any motion, we compare it with others; and when the ſame law is obſerved in both the one and the other, we may conclude that the motion compared is uniform. Thus if ſeveral bodies move at ſuch a rate that the ſpaces deſcribed in the ſame time are always to each other, either preciſely or very nearly ſo, in the ſame ratio, the motion of theſe bodies, we conclude, is either preciſely, or at leaſt very nearly uniform. For if a body A which moves uniformly paſſes through the ſpace E during the time T taken at pleaſure, and another body B alſo moving uniformly, paſſes through the ſpace e; during the ſame time T, the relation of the ſpaces E, e will be always the ſame, whether the two bodies have begun to move in the ſame or in different inſtants; and it is only to uniform motion that this property belongs. Wherefore if we divide the time into parts, whether equal or unequal, and if it be obſerved that the ſpaces paſſed through by two bodies during one part of the time, are always in the ſame relation, the greater the number the parts of the time taken, the more there is reaſon to conclude that the motion of each body is uniform. None of theſe methods, it has been obſerved, poſſeſſes geometrical preciſion; but they are ſufficient, eſpecially when they are repeated and taken together, to afford a ſatisfactory concluſion, if not with regard to abſolute uniformity of motion, at leaſt with regard to a near approximation to uniform motion.

Prop. III.

19. *In uniform motions, the ſpaces deſcribed are in the compound ratio of the velocities and the ratio of the times.* This propoſition is frequently expreſſed otherwiſe thus; *The ſpaces deſcribed with an uniform motion are proportional to the products of the times and the velocities:* Or otherwiſe thus; *The ſpaces deſcribed with a uniform motion are proportional to the rectangles of the times and the velocities.*

For let S be the ſpace deſcribed with the velocity V, in the time T, and let s be the ſpace deſcribed with the velocity v, in the time t. Let another ſpace Z be deſcribed in the time T with the velocity v.

Then by propoſition 1ſt we have $S : Z = V : v$,
And by propoſition 2d $Z : s = T : t$.

By

By compoſition of ratios therefore (or by VI. 23. Euclid), we have $=\mathrm{V}\times\mathrm{T}:v\times t=\mathrm{S}\times\mathrm{Z}:s\times\mathrm{Z}$; that is, $=\mathrm{S}:s$.

The above are all equivalent expreſſions which are demonſtrated by the ſame compoſition of ratios. The products or rectangles of the times and velocities, are the products of numbers which are as the times, multiplied by numbers which are as the velocities; or the rectangles whoſe baſes are as the times, and whoſe heights are as the velocities.

Corollary.

20. *If the ſpaces deſcribed in two uniform motions be equal, the velocities are in the reciprocal proportion of the times.*

For in this caſe the products VT and $v\,t$ are equal, and therefore $\mathrm{V}:v=t:\mathrm{T}$, or $\mathrm{V}:\mathrm{v}=\frac{1}{\mathrm{T}}:\frac{1}{t}$. Or, becauſe the rectangles AC, DF (fig. 4.) are in this caſe equal, we have (by VI. 14. Euclid) $\mathrm{AB}:\mathrm{BF}=\mathrm{BD}:\mathrm{BC}$, that is $\mathrm{V}:v=t:\mathrm{T}$.

Prop. IV.

21. *In uniform motions, the times are as the ſpaces, directly, and as the velocities, inverſely.*

For by Prop. III. $\mathrm{S}:s=\mathrm{VT}:v\,t$;
Therefore, $\mathrm{S}\,v\,t=s\mathrm{VT}$,
And, $\mathrm{T}:t=\mathrm{S}\,v:s\mathrm{V}$.

Or, $\mathrm{T}:t=\frac{\mathrm{S}}{\mathrm{V}}:\frac{s}{v}$,

And, $t\doteq\frac{s}{v}$.

Prop. V.

22. *In uniform motions, the velocities are as the ſpaces, directly, and as the times, inverſely.*

For by Prop. IV. $\mathrm{S}\,v\,t=s\mathrm{VT}$,
Therefore $\mathrm{V}:v=\mathrm{S}\,t:s\mathrm{T}$.

Or, $\mathrm{V}:v=\frac{\mathrm{S}}{\mathrm{T}}:\frac{s}{t}$,

And $v\doteq\frac{s}{t}$.

23. The values of the reſults of theſe propoſitions are not changed by the abſolute magnitudes of the ſpace and time, if both are changed in the ſame ratio. The value of $\frac{12\text{ feet}}{24''}$, or of $\frac{8\text{ feet}}{16''}$, is the ſame with half a foot per ſecond. Therefore, if s' be the expreſſion of an extremely minute portion of ſpace deſcribed with this velocity in the ſmall portion of time t', the velocity v is ſtill accurately expreſſed by $\frac{s'}{t'}$

And the accurate expreſſion of the time t' is $\frac{s'}{v}$.

Sect. II. *Of Variable Motions.*

Motions obſerved in nature rarely uniform.

24. In obſerving the phenomena of nature, it rarely happens that the motions to which our attention is directed are perfectly uniform. Theſe motions, however, we diſtinctly conceive, with all their properties; and it is obviouſly of the utmoſt importance that all the deviations from uniform motions be clearly underſtood; becauſe theſe deviations afford the only marks and meaſures of the variations, and therefore of the cauſes which produce theſe changes.

25. When a body continues to move uniformly in the ſame direction, its motion, or circumſtances with reſpect to motion, have ſuffered no change. The condition of that body, therefore, muſt be allowed to be the ſame in any two portions of its path, whatever the diſtance of theſe portions may be. And becauſe a change of place is involved in the very conception of motion, the difference of place does not imply any change. Two bodies, therefore, moving with the ſame velocity in this path, or in two lines parallel to it, their condition in reſpect of motion muſt be allowed to be the ſame. Their direction is the ſame, and their rate of motion is the ſame. The velocity, therefore, and the direction of a body, are the only circumſtances which ſeem to enter into our conception of the ſtate of a body, in reſpect of motion. Changes either in the velocity, or in the direction, or in both of theſe circumſtances, include all the changes of which this condition is ſuſceptible. Let us now conſider the firſt of theſe changes, namely, changes of velocity.

Velocity and direction only conceived in motion.

Of Accelerated and Retarded Motions.

26. It has been aſcertained by experiment and obſervation, that a ſtone in falling is carried downward with greater rapidity in every ſucceſſive period of its fall. During the firſt ſecond it falls 16 feet; during the next it falls 48 feet; during the third, it falls 80 feet; during the fourth it falls 112 feet; continuing to fall, during every ſucceſſive ſecond 32 feet more than during the preceding ſecond. A body moving in this manner is ſaid to have an *accelerated motion.* But if a body be projected perpendicularly upwards, the very reverſe takes place in the circumſtances of its motion. It is obſerved to riſe with a motion which is continually *retarded.* Theſe bodies therefore are conceived to be in every ſucceeding inſtant in different ſtates of motion. The velocity of the falling body is conceived to be greater in a certain inſtant than in any preceding inſtant; as, for example, when it has fallen 144 feet its velocity is ſaid to be thrice as great as when it has fallen only 16 feet. But this inference it is evident cannot be made directly by comparing the ſpaces deſcribed in the following moments; for in theſe it falls 112 and 48 feet; or by comparing the ſpaces immediately preceding; for in theſe the body fell 80 and 16 feet. But in this expreſſion it is ſuppoſed that the variable condition of a body, called its velocity, is, in every inſtant ſuſceptible of an accurate meaſure; and yet in no moment, however ſhort, does the body deſcribe uniformly a ſpace which can be taken as the meaſure of its velocity at the beginning of that moment; becauſe the ſpace deſcribed in any moment is too great for meaſuring the velocity at the beginning of the moment, and too ſmall for the meaſure of its velocity at the end of it. Till however ſuch a meaſure is obtained, the mechanical condition of the body is not known.

27. But in a continually accelerated motion, no ſuch meaſure can be obtained. No ſpace is deſcrib-

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ed in an inſtant: for this requires time. In that inſtant, however, the body poſſeſſes what has been called a *potential velocity*, that is, a certain tendency or determination, which remaining unchanged, cauſes it to deſcribe a certain ſpace uniformly during ſome aſſignable portion of time. At another inſtant it has another determination, by which, if it be not changed, another ſpace would be uniformly deſcribed in an equal portion of time. Now it is in the difference of thoſe two determinations that its difference of mechanical condition conſiſts. The marks and meaſures of theſe determinations are known from the ſpaces which would be uniformly deſcribed. Theſe therefore muſt be carefully inveſtigated as the meaſures of the velocities; and the proportions of theſe ſpaces are to be taken as the proportions of the velocities.

PROP. VI.

28. *Let the ſtraight line* ABD (fig. 5.) *be deſcribed with a motion continually varied, it is required to determine the proportion of the velocity in the point* A, *to the velocity in any other point* C.

Let the right line *a b d*, repreſent the time of this motion along the path AD, ſo that the points *a*, *b*, *c*, *d*, may denote the inſtants of the moving body being in A, B, C, D, and the portions *a b*, *b c*, *c d*, may expreſs the times of deſcribing AB, BC, CD, that is, may be in the proportion of thoſe times; and let *a e*, perpendicular to *a d*, expreſs the velocity of the moving body at the inſtant *a*, or in the point A. Let *e g h* be a line, ſo related to the axis *a d*, that the areas *a b f e*, *b c g f*, *c d h g*, comprehended between the ordinates *a e*, *b f*, *c g*, *d h*, all perpendicular to *a d*, may be proportional to the ſpaces AB, BC, CD, deſcribed in the times *a b*, *b c*, *c d*, and let this relation hold in every part of the figure. Then the velocity in A is to the velocity in B, or C, or D, as *a e* to *b f*, or *c g*, or *d h*. Or it may be expreſſed in other words, *If the abſciſſa* a d, *of a curve* e g h, *be proportional to the time of any motion, and the areas interrupted by parallel ordinates be proportional to the ſpaces deſcribed, the velocities are proportional to thoſe ordinates.*

Make *b c* and *c d* equal, ſo as to repreſent very ſmall and equal moments of time, and make *p a* equal to one of them. Complete the rectangle *p a e q*. This will repreſent the ſpace uniformly deſcribed in the moment *p a*, with the velocity *a e* (Propoſ. 3.) Let PA be that portion of ſpace thus uniformly deſcribed in the moment *p a*. Let the lines *i m*, *k n*, parallel to *a d*, make the rectangles *b c m i*, and *c d n k*, reſpectively equal to the areas *b c g f*, and *c d h g*. If the motions along the ſpaces PA and BC had been uniform, the velocities would have been proportional to the ſpaces deſcribed (Propoſ. 1.) becauſe the times *p a*, and *b c* are equal. That is, the velocity in A would be to the velocity in C, as the rectangle *p a e q* to the area *b c g f*, that is, as *p a e q* to *b c m i*, that is, as the baſe *a e* to the baſe *c m*, becauſe the altitudes *p a* and *b c* are equal.

But the motion along the line BC is not repreſented as uniform; for the line *f g h* diverges from the axis *b d*, the ordinate *c g* being greater than *b f*. And therefore the ſpaces meaſured by theſe areas increaſe faſter than the times; and thus the figure repreſents an accelerated motion. Therefore the velocity with which BC would be uniformly deſcribed during the moment *b c*, is leſs than the velocity at the end of that moment, that is, at the inſtant *c*, or in the point C of the path; and therefore it muſt be repreſented and meaſured by a line greater than *c m*.

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In the ſame manner it is proved that *c k* repreſents and meaſures the velocity with which CD would be uniformly deſcribed during the moment *c d*. And therefore, ſince the motion along CD is alſo accelerated, the velocity at the beginning of that moment is leſs than the velocity with which it would be uniformly deſcribed in the ſame time, and muſt be repreſented by a line leſs than *c k*.

Therefore the velocity in A, is to that in C, in a leſs ratio than that of *a e* to *c m*, but in a greater ratio than that of *a e* to *c k*. But in this caſe, as long as the inſtant *b* is prior, and *d* poſterior, to the inſtant *c*, *c m* is leſs, and *c k* is greater, than *c g*. Therefore the velocity in A is to that in C in a ratio that is greater than any ratio leſs than that of *a e* to *c g*. And, conſequently the velocity in A is to that in C, as *a e* to *c g*.

It may be proved in the ſame way, with reſpect to the velocity in any other point D; and therefore the propoſition may be conſidered as demonſtrated. And had the motion along BCD, inſtead of being accelerated as in this caſe, been retarded, the ſame reaſoning would ſtill apply.

COROLLARIES.

29. Cor. 1. *The velocities in different points of the path* AD, *are in the ultimate ratio of the ſpaces deſcribed in equal ſmall moments of time.* Draw *g o* parallel to *a d*. Then the velocity in the inſtant *a*, is to that in the inſtant *c*, as *a e* to *c g*, that is, as the rectangle *p e* to the rectangle *c o*, that is, as *p a e q* to *c d h g*, nearly. As the moments are diminiſhed, the difference *g o h* between the rectangles *c g o d* and *c g h d*, diminiſhes nearly in the duplicate ratio of the moment. If then the moment be taken $\frac{1}{2}$, $\frac{1}{3}$, or $\frac{1}{4}$ of *c d*, the error *g o h* is diminiſhed to $\frac{1}{4}$, $\frac{1}{9}$, or $\frac{1}{10}$: the corollary is now manifeſt; for the ultimate ratio of *c g o d* to *c g h d* is the ratio of equality. That is, the velocity in A is to that in C, in the ultimate ratio of PA to BC deſcribed in equal ſmall moments.

There are many caſes in which the ſpaces deſcribed in very ſmall moments can be meaſured, and yet the ultimate ratio cannot be aſcertained. Theſe ſpaces muſt then be taken as meaſures of the velocity. And by taking half the ſum of the ſpaces BC and CD, for the meaſure of the velocity in the point C, the error is almoſt reduced to nothing.

30. Cor. 2. *The momentary increments of the ſpaces deſcribed, are in the compound ratio of the velocities, and the ultimate ratio of the moments.*

For the increments PA, CD are as the rectangles *p e* and *c o* ultimately, (Propoſ. 3.); and theſe are in the compound ratio of the baſe *a e*, to the baſe *d o*, and the ultimate ratio of the altitude *p a*, to the altitude *c d*. This may be expreſſed by the proportional equation $\dot{s} \doteqdot v\dot{t}$.

31. Conſequently $v \doteqdot \frac{\dot{s}}{\dot{t}}$, and $\dot{t} \doteqdot \frac{\dot{s}}{v}$. The equation

$\dot{s} \doteqdot$

$\dot{s} \doteq v\dot{t}$, $v \doteq \frac{\dot{s}}{\dot{t}}$, and $\dot{t} \doteq \frac{\dot{s}}{v}$ ſeem to be the ſame with thoſe in (23), but there the ſmall ſpace s' was deſcribed uniformly, and the equations were abſolute. In 30 and 35, $\dot{s}$ does not repreſent a ſpace uniformly deſcribed. But $\dot{S} : \dot{s}$ expreſſes the ultimate ratio of S' to s' when they are diminiſhed continually, and vaniſh together. Therefore the meaning of the equation $\dot{s} \doteq v\dot{t}$ is, that the ultimate ratio of S' to s', is the ſame with that of VT' to vt'.

32. The following is the converſe of this propoſition.

If the abſciſſa a d *of the line* e f h, *repreſent the time of a motion along the line* ABD, *and if the ordinates* a e, b f, c g, &c. *be as the velocities in the points* A, B, C, &c. *then the areas are as the ſpaces deſcribed.* This is proved by an indirect demonſtration, thus:

For if the ſpaces AB, AD, be not proportional to the areas *a b f e*, *a d h e*, they muſt be proportional to ſome other, *a b f' e*, *a d h' e*, of another line *e f' h'*, paſſing through *e*. Aſſuming this to be true, then (by Propoſ. 6.) the velocity in A is to that in B, as *a e* to *b f*. Therefore $ae : bf = ae : bf$, which is abſurd.

33. The relation between the ſpace deſcribed and the time which elapſes is the only immediate obſervation to be made on theſe variable motions. By means of the foregoing propoſitions, the mechanical condition of the body, or rather the effect and meaſure of this condition, denominated *velocity*, is inferred. The ſame inference is made in another way. Sir Iſaac Newton often repreſents the uniform lapſe of time by the uniform increaſe of an area during the motion along the line taken for the abſciſſa. The velocities or determinations to motion in the different points of this line, are inverſely proportional to the ordinates of the curve which bounds this area.

Along the ſtraight line AD, (fig. 6.) let a point move with a motion any how continually changed, and let the curve line LIH be ſo related to AD, that the area LICB is to the area LHDB as the time of moving along BC to that of moving along BD. Let this be true in every point of the line AD. Let C*c*, D*d*, be two very ſmall ſpaces deſcribed in equal times, draw the ordinates *i c*, *h d*, and draw *i k*, *hl* perpendicular to IC, HD.

The areas IC *c i*, and HD *d h* muſt be equal, becauſe they repreſent equal moments of time. It is evident alſo, that as the ſpaces C *c* and D *d* are continually diminiſhed, the ratio of IC *c i* and HD *d h* to the rectangles *k* C *c i* and *l* D *d h* continually approximates to that of equality, and that the ratio of equality is the limiting or ultimate ratio. Since therefore, the areas IC *c i* and HD *d h* are equal, the rectangles *k* C *c i* and *l* D *d h* are ultimately in the ratio of equality. Therefore their baſes *i c* and *h d* are inverſely as their altitudes C*c* and D*d*, that is, $ic : hd = Dd : Cc$. But as C*c* and D*d* are deſcribed in equal times, they are ultimately as the velocities in *c* and *d* (29). Therefore *i c* and *h d*, are inverſely as the velocities in *c* and *d*. And as the ſame reaſoning may be applied to every point of the abſciſſa, the propoſition is demonſtrated.

34. In all caſes, then, in which the relation between the ſpaces deſcribed, and the times elapſed can be diſcovered by obſervation, we diſcover the mechanical condition of the moving body, or its velocity. But in the practical application of theſe concluſions, recourſe muſt always be had to arithmetical concluſions; and the indications of theſe are the algebraic ſymbols of geometrical reaſonings. Thus any ordinate *c g*, (fig. 5.) is repreſented by v, and the portion *c d* of the abſciſſa by $\dot{t}$, and the area *c d h g*, or its equal, the rectangle *c d o g*, by $v\dot{t}$. This rectangle then being as the correſponding portion CD of the line of motion, and CD being repreſented by $\dot{s}$, we have the equation $\dot{s} = v\dot{t}$.

35. The mathematical conſequences of theſe repreſentations may now be aſſumed to be true; and therefore $\dot{t} = \frac{\dot{t}}{v}$, as in (23.) Algebraic ſymbols being the repreſentations of arithmetical operations, they repreſent more remotely the operations of geometry, and only becauſe the area of a rectangle is analogous to the product of numbers which are proportional to its ſides. The ſymbol $\int v\dot{t}$ being uſed to repreſent the ſum of all theſe rectangles, expreſſes the whole area *a d h e*, as well as the whole line of motion AD; and the equation may be ſtated $s = \int v\dot{t}$. In like manner $\int \frac{\dot{s}}{v}$ will be equivalent to $\int \dot{t}$, that is, to t, and will expreſs the whole time *a d*. It is plain too that $\frac{\dot{s}}{v}$ repreſents the ordinate DH of the line LKIH (fig. 6.) becauſe any portion D *d* of its abſciſſa, is properly repreſented by $\dot{s}$, and the ordinates are reciprocally proportional to the velocities, that is, are proportional to the quotients of ſome conſtant number divided by the velocities, and therefore to $\frac{1}{v}$. And as $\dot{t}$ is repreſented by the rectangle *k* C *c i*, which is alſo repreſented by $\dot{s} \times \frac{1}{v}$, we have $\dot{t} = \frac{\dot{s}}{v}$, and $t = \int \frac{\dot{s}}{v}$, as above.

36. In one caſe of varied motion, when the line *efg h* (fig. 5.) is a ſtraight line, the characters are very particular and uſeful. Let this caſe of motion be repreſented along the line AD (fig. 7.) and let *pa*, *b c*, *c d*, repreſent equal moments of time, in which the moving body deſcribes PA, BC, CD; and draw *f m*, *g n*, *e s*, parallel to the abſciſſa *a d*. Now it is evident that *m g*, and *n h* are equal, or that equal increments of velocity are acquired in equal times; *e q*, *e r*, *e s*, are alſo proportional to *q f*, *r g*, *s h*, and therefore the increments *q f*, *r g*, *s h*, of velocity are proportional to the times *a b*, *a c*, *a d*, in which they are acquired. This motion may very properly be denominated *uniformly accelerated*; for here the velocity increaſes in the ſame ratio with the times, and equal increments are acquired in equal times. If the line *e h* cut the abſciſſa in *v*, it will repreſent a motion uniformly accelerated from reſt, during the time *v d*, and thus exhibit the relations between the ſpaces, velocities, and times in ſuch motions.

Hence it follows from this mode of expreſſing theſe relations,

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relations that *in motions uniformly accelerated from a ſtate of reſt, the acquired velocities are proportional to the times from the beginning of the motion.* For $a\,e$, $b\,f$, $c\,g$, $d\,h$, repreſent the velocities gained during the times $v\,a$, $v\,b$, $v\,c$, $v\,d$, and are in the ſame proportion with thoſe lines.

37.—1. Alſo, *the momentary increments of velocity, are as the moments in which they are acquired.*

2. Alſo, *the ſpaces deſcribed from the beginning of the motion, are as the ſquares of the times.*

3. Alſo, *the increments of the ſpaces are as the increments of the ſquares of the times; reckoning from the beginning of the motion.*

4. Alſo, *the ſpaces deſcribed from the beginning of the motion, are as the ſquares of the acquired velocities.*

5. Alſo, *the momentary increments of the ſpaces are as the momentary increments of the ſquares of the velocities.*

6. Alſo, *the ſpace deſcribed during any portion of time by a motion uniformly accelerated from reſt, is one-half of the ſpace uniformly deſcribed in the ſame time with the final velocity of the accelerated motion.*

7. *And the ſpace deſcribed during any portion of the time of the accelerated motion, is equal to that which would be deſcribed in the ſame time with the mean between the velocities at the beginning and end of this portion of time.*

In the inveſtigation of all other varied motions, the properties of uniformly accelerated motion ſtated above, will be found extremely uſeful, and eſpecially in caſes where approximation only can be eaſily obtained. But for the fuller illuſtration of theſe properties the reader is referred to Robiſon's Elements of Mechanical Philoſophy, p. 38.

38. Suppoſing the acceleration to be always the ſame, we conceive of this conſtancy, that in equal times there are equal increments of velocity; and therefore that the augmentations of velocity are proportional to the times in which they are acquired. That acceleration then, according to this ſuppoſition, muſt be accounted double, or triple, &c. where the velocity acquired is double or triple. And, acceleration being conſidered as a meaſurable quantity, the augmentation of velocity uniformly acquired in any given time is its meaſure.

COROLLARY.

39. *Therefore accelerations are proportional to the ſpaces deſcribed in equal times, with motions uniformly accelerated from a ſtate of reſt.* For in this caſe the ſpaces are the halves of what would be uniformly deſcribed in the ſame time with the acquired final velocities, and are therefore proportional to theſe velocities, or to the accelerations, ſince the velocities were acquired in equal times.

40. It is then ſaid, *that accelerations are proportional to the increments of velocity uniformly acquired, directly, and to the times in which they are acquired inverſely.*

$$A : a = \frac{V}{T} : \frac{v}{t}.$$

This relation between acceleration, velocity, and time, is alſo true, in uniformly accelerated motion, with reſpect to all momentary changes of velocity, as well as to thoſe caſes of motion paſſing through all degrees of velocity from nothing to the final magnitude v. For the velocity increaſing at the ſame rate with the time, we have $v : v' = t : t'$; and v' and t' expreſs the ſimultaneous increments of velocity and time.

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41. But if the augmentation of velocity be the meaſure of the acceleration, and therefore proportional to it, and if in uniformly accelerated motions, the velocity increaſes at the ſame rate with the times, the increments of velocity are as the accelerations and as the times jointly. Hence the proportional equation

$$v \doteqdot a\,t,$$
$$\text{and}\quad v' \doteqdot a\,t'.$$

42. It appears from (39.), that when the velocity has uniformly increaſed from nothing, the ſpaces deſcribed in equal times are proper meaſures of acceleration. And in (37.—3.) uniformly accelerated motions, the ſpaces are as the ſquares of the times. Therefore, when the acceleration continues the ſame, the fraction $\frac{s}{t^2}$ muſt alſo remain of the ſame value, and a is proportional to $\frac{s}{t^2}$. And therefore, *accelerations are proportional to the ſpaces deſcribed with a motion uniformly accelerated from reſt, directly, and to the ſquares of the times inverſely.*

43. And ſince $a \doteqdot \frac{v}{t}$, we have $a \doteqdot \frac{v\,v}{v\,t}$; but $v\,t \doteqdot s$, therefore $a \doteqdot \frac{v^2}{s}$. Therefore we have another meaſure of acceleration, viz. Accelerations are directly as the ſquares of the velocities, and inverſely as the ſpaces along which the velocities are uniformly augmented.

44. But when the ſpaces are equal, we have $a \doteqdot v^2$, and in uniformly accelerated motions, that is, when a remains conſtant, the ſpace being increaſed in any proportion, v^2 increaſes in the ſame proportion; it follows that v^2 increaſes in the proportion both of the acceleration and of the ſpace. And therefore, in general, we have, $v^2 \doteqdot a\,s$. And, as in 41, 42, we ſhall have $v^2 \doteqdot a\,S$, and $V^2 - v^2 \doteqdot a\,S - a\,s$, or $\doteqdot S - s$, which may be thus expreſſed $v\,v' \doteqdot a\,s'$, that is, *in a motion uniformly accelerated, the momentary change of the ſquare of the velocity is proportional to the acceleration and to the ſpace jointly.* Thus it appears, that the acceleration continued during a given time t, or t', produces a certain augmentation of the ſimple velocity; but the acceleration continued along a given ſpace s, or S', produces a certain augmentation of the ſquare of the velocity.

45. But accelerations which are conſtant and uniform, and ſuch as have been conſidered, are very rare in the phenomena of nature. They are as variable as velocities, and therefore it is not leſs difficult to diſcover their actual meaſure. By changes of velocity only we obtain any knowledge of the changing cauſe. From the continual acceleration of a falling body we learn, that the ſame power which makes it preſs on the hand, preſſes it downward, as it falls through the air; and whatever be the rapidity of its deſcent, it is from obſerving that it acquires equal increments of velocity in equal times, that we know the downward preſſure to be the ſame.

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In the ſame way that we obtain meaſures of a velocity which is continually varying, we may obtain accurate meaſures of a ſimilarly varying acceleration. A line may be conceived to increaſe along with the velocity, and at the ſame rate; and this rate of increaſe of velocity is what is called *acceleration*, in the ſame way as the rate at which the line increaſes, is what is called *velocity*. If, then, we conſider the areas (fig. 5.) or the line AD, as repreſenting a velocity; the ordinates to the line *e g h*, which were demonſtrated to be proportional to the rate of variation of the area, will be proportional to the variation of the velocity, that is, to the acceleration.

Prop. VII.

46. *If the abſciſſa* a d *of a curve line* e g h *repreſent the time of a motion, and if the areas* a b f e, a c g e, a d h e, &c. *are proportioned to the velocities at the inſtants* b, c, d, &c. *then the ordinates* a e, b f, c g, d h, &c. *are proportional to the accelerations at the inſtants* a, b, c, d, &c.

By ſubſtituting the word acceleration for the word velocity, the ſame demonſtration may be applied here as in Prop. 6. (28.) From this propoſition may be deduced ſome corollaries of practical uſe in mechanical diſcuſſions.

47. *The momentary increments of velocity are as the accelerations, and as the moments jointly.*

For the increment of velocity in the moment *c d* is accurately repreſented by the area *c d h g*, or by the rectangle *c d n k;* and *c d* accurately repreſents the moment. Alſo, the ultimate ratio of *c k* to ſuch another ordinate *b i*, is the ratio of *c g* to *b f;* that is, the ratio of the acceleration in the inſtant *c* to that in the inſtant *b*. And therefore the increment of velocity during the moment *p a* is to that during the moment *c d* as $pa \times ae$ to $cd \times dg$. Or it may be expreſſed by the proportional equation $\dot{v} \div a\dot{t}$.

48. Converſely. The acceleration *a* is proportional to $\frac{\dot{v}}{\dot{t}}$, as in the caſe when the motion is uniformly accelerated (40.)

And as the area of this figure is analogous to the ſum of all the inſcribed rectangles, when the circumſtances of the caſe admit of its being meaſured, it may be expreſſed by $\int a\dot{t}$; and thus is obtained the whole velocity acquired during the time AC, and we ſay $v \doteqdot \int a\dot{t}$.

The intenſities (or at leaſt their proportions) of the accelerating power of nature in the different points of the path being frequently known, we wiſh to diſcover the velocities in thoſe points. This may be done by the following propoſition.

Prop. VIII.

49. *If the abſciſſa* AE (fig. 8.) *of a line* a c e *be the ſpace along which a body moves with a motion continually varied, and if the ordinates* A *a*, B *b*, C *c*, &c. *be proportional to the accelerations in the points* A, B, C, &c. *then the areas* AB *b a*, AD *d a*, AE *e a*, &c. *are proportional to the augmentations of the ſquare of the velocity in* A *at the points* B, D, E, &c.

Compound Motions.

Take BC, CD, as two very ſmall portions of the line AE, and draw *b f*, *c g*, parallel to AE. Then, ſuppoſing the acceleration B *b*, to continue through the ſpace BC, the rectangle B *b f* C will expreſs the augmentation made on the ſquare of the velocity in B. In the ſame way C *c g* D will expreſs the augmentation of the ſquare of the velocity in C; and, in like manner, the rectangles inſcribed in the remainder of the figure will expreſs the increments of the ſquares of the velocity acquired, while the body moves over the correſponding portions of the abſciſſa. And, therefore, the whole augmentation of the ſquare of the velocity in A (ſhould there be any velocity in that point) during the time of moving from A to B, will conſtitute the aggregate of theſe partial increments. The ſame thing muſt be affirmed of the motion from B to E. And, when the ſubdiviſion of AE is carried on without end, it is plain that the ultimate ratio of the area AE *e a* to the aggregate of inſcribed rectangles, is that of equality; that is, when the acceleration varies continually, the area AB *b a* will expreſs the increment made on the ſquare of the initial velocity in A, while the body moves along AB; and the ſame muſt be affirmed with reſpect to the motion along BE. And, therefore, the intercepted areas AB *b a*, BD *d b*, DE *e d*, are proportional to the changes made on the ſquares of the velocities in the points A, B, and D.

Corollaries.

50. Cor. 1. *If the body had no velocity in* A, *the areas* AB *b a*, AD *d a*, &c. *are proportional to the ſquares of the velocity acquired in the points* B, D, &c.

Cor. 2. *The momentary change on the ſquare of the velocity, is as the acceleration and increment of the ſpace jointly;* or we have $v\dot{v} = a\dot{s}$.

Cor. 3. $v\dot{v}$ *being equal to half the increment of the ſquare of the velocity, it follows that the area* AE *e a*, *or the fluent* $\int a\dot{s}$ *is only equal to* $\frac{V^2 - v^2}{2}$, *taking* v *and* V *as the velocities in* A *and* E.

51. What has now been ſaid of the acceleration of motion, is equally applicable to motions that are retarded, whether theſe motions be uniform or unequable. The momentary variations in this caſe are to be taken as decrements of velocity inſtead of increments. A moving body, ſubject to uniform retardation till it come to reſt, will continue in motion during a time proportional to the initial velocity; and deſcribe a ſpace proportional to the ſquare of this velocity; and the ſpace which is ſo deſcribed, is one half what it would have been if the initial velocity had continued undiminiſhed.

Sect. III. *Of Compound Motions.*

Characteriſtics in changes of direction

52. Having obtained the marks and meaſures of every variation of velocity, we are now to diſcover ſimilar characteriſtics for every change of direction. In the above inveſtigation of the general marks of any change of motion, it is plain that the change being the ſame in any two or more inſtances, the oſtenſible marks muſt alſo be the ſame, whatever may have been the previous

previous condition of the moving bodies. In every caſe of change, ſome circumſtance in the difference between the former motions and the new motions muſt be obſerved, which is exactly the ſame both in reſpect of velocity and of direction. One of the bodies then may be ſuppoſed to have been at reſt; and thus the change produced on it, is the motion which it has acquired, or the determination to this motion. Therefore, *a change of motion is itſelf a motion, or determination to motion.* In the above caſe, it is the new motion only; but it is not the new motion in every other caſe. For ſuppoſing the previous condition of the body to have been different from that of a body at reſt, and ſuppoſing the ſame change produced on it, the new condition of the one body muſt be different from the new condition of the other. The change, therefore, being the ſame in both caſes, the new condition cannot be that *change.* But, when the ſame change happens in any previous motion, the difference between the former motion and the new motion, muſt indicate ſomething that is equivalent to the motion produced in a body previouſly at reſt, or the ſame with that motion, this body having received the ſame change. And the difference between the new motions of the two bodies will be ſuch as ſhall indicate the difference between the previous conditions of each body. The change of motion then is itſelf a motion; and this being aſſumed as a principle, we are now to endeavour to diſcover a motion, which alone ſhall produce that difference from the former motion, which, in all caſes, is obſerved in the new motion. This is to be conſidered as the proper characteriſtic of the change.

Illuſtrated, 53. The following motions may ſerve as an illuſtration of theſe conditions. Let it be ſuppoſed that the ſtraight line AB (fig. 9.) lies eaſt and weſt, and that it is croſſed by the line AC from north to ſouth. Suppoſe this line AC to be a rod or wire, and to be carried along the line AB in one minute, but always in the ſame poſition, that is, lying north and ſouth. The end of the rod or wire A having moved uniformly one-third of AB at the end of 20″, it will be in the poſition D d ∂; at the end of 40″ it will have the poſition E *e* ε; and at the end of the minute it will be in the poſition B *b*.

Let the line AB, in the mean time, (ſuppoſing it alſo to be material) be uniformly moved from north to ſouth, and always parallel to its firſt poſition AB. When it has paſſed over one-third of AC, at the end of 20″, it will be in the poſition m d n; at the end of 40″ it will have the poſition o e p, and A o is two-thirds of AC. At the end of the minute, it will have the poſition C ∂ ε b. It is evident that the common interſection of theſe two lines will be always in the diagonal A b of the parallelogram AC b B; for the parallelogram A m d D is ſimilar to the parallelogram AC b B, becauſe AD : AB = A m : AC; and, in like manner, A o e E is a parallelogram ſimilar to AC b B. Therefore, theſe parallelograms are about a common diagonal A b.

Again, the motion of the point of interſection of theſe lines is uniform; for AD : AB = A d : A b, and AE : AB = A e : A b, &c. Therefore the ſpaces A d, A e, A b are proportional to the times.

Thus the interſection of two lines having each a uniform motion in the direction of the other, moves uniformly in the direction of the diagonal of the parallelogram, which is formed by the lines in their firſt or laſt poſition; and the velocity of the interſection is to the velocity of each of the motions of the lines as the diagonal is to the ſide in the direction of which the motions are made. This motion of the interſection is very properly ſaid to be compounded of two motions in the direction of the ſides; for which the point d of the line D ∂ moves eaſtward, the ſame point d of the line m d n is at the ſame inſtant moving ſouthward. The point d, therefore, may be conſidered as a point of both lines, partaking in every inſtant of both motions. The motion along A b then contains both motions along AB and AC, and being identical with a motion compounded of theſe motions, indicates both, or the determination to both. In every ſituation of the point of interſection, its velocity is compounded of the velocity AB and AC. A body, therefore, whoſe motion continued unchanged, would have deſcribed AB in one minute; but when it reaches the point A, it turns aſide, and deſcribes A b uniformly in the ſame time; the change then which the body ſuſtains in the point A is a motion AC. For ſuppoſe the body had been at reſt in the point A, and it is obſerved to deſcribe AC in one minute, the motion AC is the change which it has ſuſtained. The motion A b is not the change: for if AF had been the primitive motion, the ſame motion A b would have been the reſult of compounding with it the motion AG. But ſince AF is different from AB, the ſame change cannot produce the ſame new conditions. But, farther, there is no other motion which, by compounding it with AB, will produce the motion A b; and the motion AC is the only circumſtance of ſameneſs between changing the motion AB into the diagonal motion A b, and giving the motion AC to a body which was previouſly at reſt.—From theſe conditions it follows, *that a change of motion, is that motion, which by compoſition with the previous ſtate of motion, produces the new motion.*

and in another way. 54. This compoſition of motion has been conſidered in a different way. While a body is ſuppoſed to move uniformly in the direction AB, the ſpace in which this motion is performed, is ſuppoſed to be carried in the direction AC. But it cannot be conceived that any portion of ſpace is moved from its place. A diſtinct notion of this compoſition may be obtained, by ſuppoſing a perſon walking along a line AB, while this is drawn on a piece of ice, and the ice is floating in the direction AC. But the motion on moving ice is not preciſely a compoſition of two determinations to motion; for this is completed in the firſt inſtant. When the motion in the direction and with the velocity A b begins, no further exertion is needed; the motion continues, and A b is deſcribed. It ſerves, however, to exhibit to the mind the mathematical compoſition of two motions. In the reſult of this combination, all the characteriſtics of the two determinations are to be found; for the point of interſection, in whatever way it is conſidered, partakes of both motions.

55. Thus a general characteriſtic of a change of motion is obtained, and this correſponds with the mark and meaſure of every moving cauſe; for it is the very motion which it is conceived to produce. It may perhaps even be conſidered as the foundation of former meaſures; for in every acceleration, retardation, or deflection, there is a new motion compounded with the former.

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former. What is taken for the beginning of motion in every obſervation of ſurrounding bodies, is nothing more than a change induced on a motion already produced.

56. The actual compoſition of motion being ſo general in the phenomena of the univerſe, it obtains in all motions and changes of motion produced or obſerved, and the characteriſtic which has been aſſumed of a change of motion being the ſame, whatever may have been the previous motion, and this being equally applicable to ſimple motions, it is evident that a knowledge of the general reſults of this compoſition of motion will be of eſſential ſervice in acquiring a knowledge of mechanical nature.

57. The following is the general theorem to which all others may be reduced.

Prop. IX.

Two uniform motions, having the directions and velocities repreſented by the ſides AB, AC, *of a parallelogram, compoſe a uniform motion in the diagonal.* The demonſtration of this has been already given. The motion of the point of interſection of theſe two lines, each moving uniformly in all its points, in the direction of the other, is, in every inſtant, compoſed of the two motions. It is the ſame as if a point deſcribed AB uniformly, while AB is carried uniformly in the direction AC. This motion is along the diagonal A b, and it has been already ſhewn to be uniform. And, becauſe AB and A b are deſcribed in the ſame time, the velocities of the motions along AB, AC, and A b are proportional to thoſe lines.

Corollaries.

Cor. 1. *The motion* A b, *which is compounded of the two ſimple motions* AB *and* AC, *is in the ſame plane with theſe motions. For a parallelogram lies all in the ſame plane.*

Cor. 2. *The motion* A b *may be produced by the compoſition of any two uniform motions having the direction and velocities which are repreſented by the ſides of any parallelogram* AF b G, or AC b B, *which has* A b *for its diagonal.*

How to aſcertain the proportion of the velocity in compound motions.

58. Caſes are not unfrequent in which the directions of two ſimple motions compoſing an obſerved motion may be diſcovered; but the proportion of the velocities is unknown. This velocity may be aſcertained by means of this laſt propoſition. For the direction of the three motions, namely, the two ſimple and the compound motions, determines not only the ſpecies of parallelogram, but alſo the ratio of the ſides. Again, in thoſe caſes in which the direction and the velocity of one of the ſimple motions are known, and therefore its proportion to that of the obſerved compound motion, the direction and velocity of the other may be alſo found by means of the ſame propoſition; becauſe from theſe data the parallelogram may be determined.

59. This motion in the diagonal is called the *equivalent motion*, or the *reſulting motion;* for it is equivalent to the combined motions in the ſides. Thus, if the moving body firſt deſcribe AB, and then B b or AC, it will be in the ſame point, as if it had deſcribed A b, namely, in the point b.

60. It is often highly uſeful in inveſtigations of this kind to ſubſtitute ſuch motions for an obſerved motion, as will produce it by compoſition. This has been denominated the *reſolution of motions*. By this manner of proceeding, a ſhip's change of ſituation at the end of a day, having ſailed in different courſes, is computed. Thus the diſtance ſailed to the eaſtward or the weſtward, as well as that to the northward or ſouthward, on each courſe, is obſerved and marked. The whole of the eaſtings, and the whole of the ſouthings, are added together; and then it is ſuppoſed that the ſhip has ſailed for the whole day on that courſe, which would be produced by combining the ſame eaſting and ſouthing.

Compound Motions.

61. It is alſo uſeful to conſider how much the body has been advanced in a certain direction by means of the obſerved motion; let us ſuppoſe in the direction AB (fig. 10.) The motion CD is firſt conſidered as compoſed of a motion CE parallel to the given line AB, and another motion CF perpendicular to AB. CD is the diagonal of a parallelogram CEDF, one of whoſe ſides CE is parallel to AB, and the other CF is perpendicular to AB. It is evident, that the body has advanced in the direction of AB as much as if it had moved from G to H, inſtead of moving from C to D, ſo that the motion CF has no effect either in obſtructing or promoting the progreſs in AB. This is called *eſtimating* a motion in a given direction, or *reducing* it to that direction.

62. A motion is alſo ſaid to be eſtimated in a given plane, when it is conſidered as compoſed of a motion perpendicular to the plane, and of another parallel to it. In a given plane ABCD (fig. 11.), let EF be a motion compounded of a motion GE perpendicular to the plane, and EH parallel to it. For if the lines GE, FH are drawn perpendicular to the plane, they cut it in two points e and f, and EH is parallel to e f.

63. In the ſame way a compound motion may be formed of any number of motions. Let AB, AC, AD, AE, &c. (fig. 12.) be any number of motions, of which the motion AF is compounded. The motion which is the reſult of this compoſition is thus aſcertained. The motion AG is compounded of AB and AC; and the motion AG compounded with AD, gives the motion AH; which latter being compounded with AE, produces the motion AF. And the ſame place, or final ſituation F, will be found by ſuppoſing the different motions AB, AC, AD, AE, to be performed ſucceſſively. The moving body firſt deſcribes AB; then BG, equal and parallel to AC; then GH, equal and parallel to AD; and laſtly, HF, equal and parallel to AE. In this caſe it is not requiſite that all the motions lie in the ſame plane.

64. Three motions which have the direction and proportions of the ſides of a parallelopiped, compoſe a motion having the direction of its diagonal. Let AB, AC, AD (fig. 13.), be theſe motions, the compounded motion is in the diagonal AF of the parallelopiped; becauſe AB and AC compoſe the motion AE; and AE and AD compoſe the motion AF.

It is in this way that the mine-ſurveyor proceeds. He ſets down a gallery of a mine, not directly by its real poſition, but marks the eaſting and weſting, the northing and ſouthing, as well as its dip and riſe. All theſe meaſures are referred to three lines, of which one runs eaſt and weſt, one north and ſouth, and a third is perpendicular. Theſe three lines are obviouſly analogous

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gous to the angular boundaries of a rectangular box, as AC, AB, AD.

Other compound motions.

65. The compoſition of uniform motions only has yet been conſidered. But it is eaſy to conceive that any motions may be compounded. It is a caſe of this kind when a man is ſuppoſed to walk on a field of ice along a crooked path, while the ice floats down a crooked ſtream. Suppoſe a uniform motion in the direction AB (fig. 14.), to be compounded with a uniformly accelerated motion in the direction AC. A ſtone falling from the maſt head of a ſhip, while ſhe ſails uniformly forward in the direction AB, affords an example of this kind of motion; for the ſtone will be obſerved to fall parallel to a plummet hung from the maſt head. But the real motion of the ſtone is a parabolic arch $Abfg$, which AB touches in A; for while the maſt head deſcribes the equal lines AB, BF, FG, the ſtone has fallen to β and ϕ and γ, and the line AC is in the poſitions BB', FF', GG', ſo that $A\phi$ is four times $A\beta$; and $A\gamma$ is nine times $A\beta$. Therefore $A\beta$, $A\phi$, $A\gamma$, are as the ſquares of βb, ϕf, γg, and the line $Abfg$ is a *parabola*.

Condition of compound motions diſcovered from that of the ſimple motions.

66. Knowing the direction and velocities of each of the ſimple motions in any inſtant, of which two motions, however variable, are compounded, we may diſcover the direction and velocities of the compound motions in that inſtant. For it may be ſuppoſed that each motion at that inſtant proceeds unchanged: a parallelogram is then conſtructed; the ſides of which have the directions and proportions of the velocities of the ſimple motions; and the diagonal of this parallelogram will expreſs the direction and velocity of the compound motion. But on the other hand, if the direction and velocity of the compound motion, with the directions of each of the ſimple motions, be known, we may diſcover their velocities.

67. In caſes where a curvilineal motion as ABC (fig. 15.), is the reſult of two motions compounded, of which the direction is known to be AD and AE, we diſcover the velocities of the three motions in any point B, by drawing the tangent BF, and the ordinate BG, parallel to one of the ſimple motions, and from any point H in that ordinate drawing HF parallel to the other motion, and cutting the tangent in the point F. The three velocities are in the proportion of the three lines FH, HB, and FB.

Danger of miſtakes about changes of motion.

68. As the motions which are obſerved in nature are very different from what they are taken to be, it is not eaſy to avoid miſtakes with reſpect to the changes of motion, and conſequently with reſpect to the inference of its cauſe. Without conſidering the real motion of any body, we are apt to judge only of the change of diſtance and direction in relation to ourſelves. Thus it is that our inferences with regard to the planetary motions are very different from the motions themſelves, if the rapid motion of our earth be conſidered.

PROP. X.

69. *The motion of one body in relation to another body, or as it is ſeen from another body, which is alſo in motion, is compounded of its own real motion, and the oppoſite of the real motion of the ſecond body.*

Let A (fig. 16.) be a body in motion from A to C, as ſeen from B, which is another body in motion from B to D the motion of A is compounded of its own real motion, and of the oppoſite to the real motion of B. Join AB, and draw AE equal and parallel to BD. Complete the parallelogram ACFE, and join ED and DC. Produce EA, and make AL equal to AE or BD. Complete the parallelogram LACK, and draw AK and BK. If then A had moved along AE while B moves along BD, the two bodies would have been at E and D, at the ſame time, and would have the ſame relative ſituation; they would have the ſame bearing and diſtance as before. And if the ſpectator in B is not ſenſible of his own motion, A will appear not to have changed its place. In the ſame way two ſhips becalmed in an unknown current, ſeem to the perſons on board to be at reſt. The real poſition, therefore, and diſtance DC, are the ſame with BK; and if a ſpectator in B imagines himſelf at reſt, the line AK will be taken as the motion of A. And this motion, it is obvious, is compoſed of the motion AC its real motion, and the motion AL which is the equal and oppoſite motion to that of BD.

Motions continually deflected.

Again, if BH be drawn equal and oppoſite to AC, and the parallelogram BHGD be completed, and BG and AG be drawn, the diagonal BG will be the motion of B as it is ſeen from A. Now as KAGB is a parallelogram, the relative ſituation and diſtances of A and B at the end of the motion will appear to be the ſame as in the former caſe. For B appears to have moved along BG, which is equal and oppoſite to AK. Hence it follows, that the apparent or relative motions of two bodies are equal and oppoſite, whatever their real motions may be; and therefore they do not afford any information of their real motions.

70. Suppoſe equal and parallel motions are compounded with all and each of the motions of any number of bodies, moving in any manner of way, then their relative motions are not conſequently changed. For if it be compounded with the motion of any one of the bodies which may be called A, the real motion of this body is changed; but its apparent motion as ſeen from another body B, is compounded of the real change, and of the oppoſite to the real change in A, which therefore deſtroys that change, and the relative motion of A is the ſame as before. Thus it is that the motions in the cabin of a ſhip are not affected by the ſhip's progreſſive motion; and the motion of the earth round the ſun produces no perceptible effect on the relative motions on its ſurface. And indeed it is only by obſerving other bodies which are not affected by theſe common motions, and to which we refer as to fixed points, that we arrive at any knowledge of them.

SECT. IV. *Of Motions continually Deflected.*

Great variety of curvilineal motions.

71. CURVILINEAL motions are caſes of continual deflection. They are ſuſceptible of great varieties; and the inveſtigation of their modifications and chief properties is attended with no ſmall difficulty. Uniform motion in a circular arch is an example of the ſimpleſt caſe of curvilineal motion; for here the deflections from rectilineal motion are equal in equal times. If, however, the velocity be increaſed, the momentary deflection muſt alſo be augmented; for a greater arch will be deſcribed, and the end of this greater arch is at

Motions continually deflected.

at a greater diſtance from the tangent. But the proportion of this augmentation is difficult to be aſcertained.

When a uniform rectilineal motion AB (fig. 17.) is deflected into another BC, the linear deflection is aſcertained by drawing a line from the point *c*, at which point the body would have arrived, had it not been deflected to the point C at which it has arrived. The reſult is the ſame, whether the lines d D or c C be drawn in this manner; for being proportional to B *d*, B *c*, they always give the ſame meaſure of the velocities; and here the lines of deflection are all parallel, indicating the direction of the deflection in the point B. But this is not the caſe in any curvilineal motion. It rarely happens that *d* D, *c* C, are parallel; and it is never found that $d\text{D} : c\text{C} = \text{B}d : \text{B}c$. We cannot therefore diſcover which lines ſhould be taken for the indication of the direction of the deflection at B, or for the meaſure of its magnitude. A greater velocity then, in the ſame curve, produces a greater deflection; but if the path be more incurvated, an arch of the ſame length deſcribed with the ſame velocity, cauſes a farther deviation from the tangent. If therefore a body have a uniform motion in a curve of variable curvature, the deflection is greateſt where the curvature is greateſt.

Thus it appears that the direction and meaſure of the deflections by which a body deviates continually into a curvilineal path cannot be aſcertained, but by inveſtigating the ultimate poſitions and ratios of the lines, which join the points of the curve with the ſimultaneous points of the tangent, as the points δ and C are taken nearer to B. In ſome caſes, but rarely, the lines joining the ſimultaneous points are parallel. But in moſt caſes the direction of the deflection is diſcovered by obſerving to what direction it approximates. The following propoſition which was diſcovered by Newton is of great importance in this inveſtigation.

Prop. XI.

72. *If a body deſcribe a curve line* ABCDEF (fig. 18.) *being in the ſame plane, and if in this plane there be a point* S *ſo ſituated, that the lines* SA, SB, SC, &c. *drawn to the curve, cut off areas* ASB, ASC, ASD, &c. *proportional to the times of deſcribing the arches* AB, AC, AD, &c. *then the deflections are always directed to the point* S.

Suppoſe firſt that the body deſcribes the polygon ABCDEF, formed of the chords of this curve, and that it deſcribes each chord uniformly, and is deflected only in the angles B, C, D, &c. Suppoſe alſo that the ſides of the polygon are deſcribed in equal times, ſo that, according to the hypotheſis, the triangles ASB, BSC, CSD, are all equal. Continue the chords AB, BC, &c. beyond the arches, making B *c* equal to AB, and C *d* equal to BC, and ſo on. Join *c* C, *d* D, &c. and draw *c* S, S *d*, &c.; draw C *b* parallel to *c* B or BA, cutting BS in *b*, and join *b* A, and draw CA, cutting B *b* in *o*. And laſtly, make a ſimilar conſtruction at E.

Then, becauſe *c* B is equal to BA, the triangles ASB and BS *c*, are equal, and therefore BS *c* is equal to BSC. And being on the ſame baſe SB, they are therefore between the ſame parallels; that is, *c* C is parallel to BS, and BC is the diagonal of a parallelogram B *b* C *c*. The motion BC is therefore compounded of the motions B *c* and B *b*, and B *b* is the deflection, by which the motion B *c* is changed into the motion BC; and therefore the deflection in B is directed to S. By ſimilar reaſoning it may be ſhown that *f* F, or E *i*, is the deflection at E, and is likewiſe directed to S; and the ſame demonſtration will apply to every angle of the polygon.—This point S has been called the centre of deflection.

If the ſides of the polygon are diminiſhed, and their number infinitely increaſed, the demonſtration remains the ſame, and continues, when the polygon coaleſces with the curvilineal area, and its ſides with the curvilineal arch.

But when the whole areas are proportional to the times, equal areas are deſcribed in equal times. In ſuch motion therefore, the deflections are always directed to S.

Prop. XII.

73. *If the deflection by which a curve line is deſcribed, be continually directed to a fixed point, the figure will be in one plane, and areas will be deſcribed round that point proportional to the times.* Let ADF be the curve line deſcribed, and let the deflections be directed to the point S, this curve line is in the ſame plane. For BC is the diagonal of a parallelogram, and is in the plane of SB and B *c*; and *c* C is parallel to BS, and the triangles SBC, SB *c*, and SBA, are equal. But equal areas are deſcribed in equal times; and therefore areas are deſcribed proportional to the times.

Corollaries.

74. Cor. 1. *The velocities in different points of the curve are inverſely proportional to the perpendiculars* S r *and* S t (fig. 19.) *drawn from* S *on the tangents* A r, E t *in thoſe points of the curve.* For ſince the elementary triangles ASB, ESF, are equal, their baſes AB, EF, are inverſely as their altitudes S *r*, S *t*. And theſe baſes being deſcribed in equal times are as the velocities, and ultimately coincide with the tangents at A and E; and therefore the velocity in A is to that in E as S *t* to S *r*.

Cor. 2. *The angular velocities round* S *are inverſely as the ſquares of the diſtances.* For if we deſcribe round the centre S the ſmall arches B a, F δ, they may be conſidered as perpendiculars on SA and SE. Deſcribe alſo with the diſtance SF the arch *g h*. It is evident that *g h* is to F δ as the angle ASB to the angle ESF. And ſince the areas ASB, ESF are equal, we have $\text{B a} : \text{F}\delta = \text{SE} : \text{SA}$.

But $gh : \text{B a} = \text{SE} : \text{SA}$
Therefore $gh : \text{F}\delta = \text{SE}^2 : \text{SA}^2$
And $\text{ASB} : \text{ESF} = \text{SE}^2 : \text{SA}^2$.

75. Let us now proceed to determine the magnitude of the deflection, or to compare its magnitude in any two points, as for example the magnitude in B (fig. 18.) with its magnitude in E. The deflection in B is to that in E as the line B *b* to the line E *i*; for B *b* and E *i* are the motions, which, by being compounded with the motions B *c* and E *f* make the body deſcribe BC and EF. And therefore when the ſides of the polygon

Motions continually deflected.

lygon are infinitely diminiſhed, the ultimate ratio of B b to E i is the ratio of the deflection at B to the deflection at E.

To obtain a convenient expreſſion of this ultimate ratio, let ABCXZY be a circle which paſſes through the points A, B, C. Draw BSZ through the point S, and draw CZ, AZ. Now the triangles BC b and AZC are ſimilar, for C b was drawn parallel to c B or BA; and therefore the angle C b B is equal to the alternate angle b BA or ZBA, which is equal to the angle ZCA, becauſe it is ſubtended by the ſame chord ZA; and becauſe they ſtand on the ſame chord CZ, CB b, or CBZ, is equal to CAZ. And therefore the remaining angles b CB and CZA are equal, and the triangles are ſimilar. Therefore B b : CA=BC : AZ.

Now if the ſides of the polygon are continually diminiſhed, the points A and C continually approach to B, and CA continually approaches to c A, or to 2 c B, or 2 CB, and is ultimately equal to it; and AZ is ultimately equal to BZ.

Therefore ultimately, B b : 2 BC=BC : BZ, and $\mathrm{B}b \times \mathrm{BZ} = 2\ \mathrm{BC}^2$, and $\mathrm{B}b = \frac{2\mathrm{BC}^2}{\mathrm{BZ}}$.

Alſo, at the point E, we have E i ultimately equal to $\frac{2\,\mathrm{EF}^2}{\mathrm{E}z}$, for E z is that chord of the circle through D, E, and F, which paſſes through i.

Therefore $\mathrm{B}b : \mathrm{E}i = \frac{2\,\mathrm{BC}^2}{\mathrm{BZ}} : \frac{2\,\mathrm{EF}^2}{\mathrm{E}z}$.

The ultimate circle, when the three points A, B, C, coaleſce, is called the *circle of equal curvature*, or the *equicurve circle*, which coaleſces with the curve in B in the cloſeſt manner; and the chord BZ of this circle, having the direction of the deflection in B, is called its *deflective chord*. And ſince BC and EF are deſcribed in equal times, they are proportional to the velocities in B and E. This propoſition therefore may be expreſſed as follows.

In curvilineal motions, the deflections in different points of the curve, are proportional to the ſquare of the velocities in thoſe points directly, and to the deflective chords of the equicurve circles, inverſely.

It ought however, to be remarked, that this theorem is not limited to curvilineal motions, in which the deflections tend always to the ſame fixed point; it may be extended to all curvilineal motions whatever. A ſymbolical expreſſion of this theorem will be convenient. If therefore the deflective chord of the equicurve circle be repreſented by c, and the deflection by d, the theorem may be thus expreſſed.

$$d \doteqdot \frac{v^2}{c}, \text{ or } d = \frac{2\ \mathrm{arch}^2}{c}.$$

76. The line B b is the linear deflection by which the uniform motion in the chord AB is changed into a uniform motion in the chord BC, or it is the deviation c C from the point to which the moving body would have arrived, if the deflection at B had not taken place. In the caſe of curvilineal motion which we are now conſidering, the lines B b and B c are expreſſions of the meaſures of the velocities of theſe motions. B c is to B b as the velocity of the progreſſive motion is to the velocity of the deflection, generated in the time that the arch BC is deſcribed. But the deflection in the arch has been continual, and like acceleration, it may be meaſured by the velocity generated during any moment of time. It may therefore be meaſured by the velocity generated during the time the arch BC is deſcribed. This meaſure will therefore be double of the ſpace through which the body is actually deflected from the tangent in B in that time. The ſpace deſcribed will be BO, or only one-half of B b. This is exactly what happens; for the tangent is ultimately parallel to OC, and it biſects c C; therefore the velocity gradually generated is that which conſtitutes the polygonal motion in the chords, although the deflection from the tangent to the curve is only half of the deflection from the produced chord to the curve.

Motions continually deflected.

77. In any point of a curvilineal motion, the velocity is that which would be generated by the deflection in that point, if continued through one-fourth of the deflective chord of the equicurve circle. Take x for the ſpace along which a body is to be accelerated that it may acquire the velocity BC.

We have $\mathrm{B}b^2$, or $4\ \mathrm{BO} : \mathrm{BC}^2 = \mathrm{B} : x$ (37.—1.); and therefore $x = \frac{\mathrm{BC}^2 \times \mathrm{BO}}{4\ \mathrm{BO}^2}, = \frac{\mathrm{BC}^2}{4\mathrm{BO}}$, and $4x = \frac{\mathrm{BC}^2}{\mathrm{BO}}$, or BO : BC=BC : $4x$. But BO : BC=BC : BZ; therefore $x = \frac{1}{4}$ BZ.

78. We have now obtained characteriſtic expreſſions, or marks and meaſures of the principal affections of motion. Theſe expreſſions may be brought into one view as follows.

The acceleration a is $\frac{\dot{v}}{\dot{t}}$ (48.), or $\frac{v\dot{v}}{\dot{s}}$ (49.), or $\frac{\dot{s}}{\dot{t}^2}$ (42.).

The momentary variation of velocity $\dot{v} = a\dot{t}$ (48.).

The momentary variation of the ſquare of velocity

$$2v\dot{v} = 2a\dot{s} \text{ (49.)}$$

The momentary deflection $d = \frac{\mathrm{arc.}^2}{\mathrm{chord}}$ (76.)

The deflective velocity $= \frac{2v^2}{c}$ (75.).

79. But for the application of theſe doctrines, it is neceſſary to ſelect ſome point in any body of ſenſible magnitude, or in any ſyſtem of bodies, by whoſe poſition or motion, a diſtinct and accurate notion of the poſition or motion of the body or ſyſtem may be formed. The condition by which the propriety of this ſelection is aſcertained, is, *that the poſition, diſtance, or motion of this point ſhall be the medium or average of the poſitions, diſtances, and motions of every particle of matter in the aggregate or ſyſtem.*

Center of poſition.

This will happen, if the point be ſo ſituated, that when a plane is made to paſs through it in any direction whatever, and perpendiculars being drawn to this plane from every particle of matter in this aggregate or ſyſtem, the ſum of the perpendiculars on the one ſide of the plane is equal to the ſum of the perpendiculars on the other ſide. And that ſuch a point, which is called the *centre of poſition*, may be found in every body, is proved by the following demonſtration.

For let P (fig. 20.) be a point ſo ſituated, and let QR be the ſection of a plane perpendicular to the paper, and at any diſtance from it, the diſtance P p of the point P from this plane is the average of all the diſtances of each particle from it. Let the plane APB paſs through P, and parallel to QR. The diſtance

CS

Motions continually deflected.

CS of any particle C from the plane QR is equal to DS—DC, or to Pp—DC. And the diſtance GT of a particle G on the other ſide of APB, is equal to HT+GH, or to Pp+GH. Let n be the number of particles on that ſide of AB which is neareſt to QR, and let o be the number of particles on the other ſide of AB. Let m be the number of particles in the whole body; we have then $m=n+o$. It is evident that the ſum of all the diſtances of all the particles ſuch as CS, is $n \times \mathrm{P}p$—the ſum of all the diſtances, ſuch as CD. Alſo the ſum of all the diſtances of the particles, ſuchas G, is $o \times \mathrm{P}p$, + the ſum of the diſtances GH. And therefore the ſum of both ſets is $n+o \times \mathrm{P}p+$ the ſum of GH— the ſum of DC, or $m \times \mathrm{P}p+$ the ſum of GH—the ſum of DC. But by the ſuppoſed property of the point P, the ſum of GH wanting the ſum of DC is nothing; and therefore $m \times \mathrm{P}p$ is the ſum of all the diſtances, and Pp is the mth part of this ſum, or the average diſtance.

Suppoſe the body to have changed both its place and its poſition with reſpect to the plane QR, and that P (fig. 21.) is ſtill the ſame point of the body, and $\alpha \mathrm{P} \beta$ a plane parallel to QR. Make $p\pi$ equal to pP of fig. 20. It is plain that Pp is ſtill the average diſtance, and that $m \times \mathrm{P}p$ is the ſum of all the preſent diſtances of the particles from QR, and that $m \times \pi p$ is the ſum of all the former diſtances. Therefore $m \times \mathrm{P}\pi$ is the ſum of all the changes of diſtance, or the whole quantity of motion eſtimated in the direction πP. Pπ is the mth part of this ſum, and is therefore the average motion in this direction. The point P has therefore been properly ſelected; and its poſition, and diſtance, and motion, in reſpect of any plane, is a proper repreſentation of the ſituation and motion of the whole.

Hence it follows, that if any particle C (fig. 20.) moves from C to N, in the line CS, the centre of the whole will be transferred from P to Q, ſo that PQ is the mth part of CN; for the ſum of all the diſtances has been diminiſhed by the quantity CN, and therefore the average diſtance muſt be diminiſhed by the mth part of CN, or PQ is $=\frac{\mathrm{CN}}{m}$.

But it may be doubted whether there is in every body a point, and but one point, ſuch that if a plane paſs through it, *in any direction whatever*, the ſum of all the diſtances of the particles on one ſide of this plane is equal to the ſum of all the diſtances on the other.

It is eaſy to ſhew that ſuch a point may be found, with reſpect to a plane parallel to QR. For if the ſum of all the diſtances DC exceed the ſum of all the diſtances GH, we have only to paſs the plane AB a little nearer to QR, but ſtill parallel to it. This will diminiſh the ſum of the lines DC, and increaſe the ſum of the lines GH. We may do this till the ſums are equal.

In like manner we can do this with reſpect to a plane LM (alſo perpendicular to the paper), perpendicular to the plane AB. The point wanted is ſomewhere in the plane AB, and ſomewhere in the plane LM. Therefore it is ſomewhere in the line in which theſe two planes interſect each other. This line paſſes through the point P of the paper where the two lines AB and LM cut each other. Theſe two lines repreſent planes, but are, in fact, only the interſection of thoſe planes with the plane of the paper. Part of the body muſt be conceived as being above the paper, and part of it behind or below the paper. The plane of the paper therefore divides the body into two parts. It may be ſo ſituated, therefore, that the ſum of all the diſtances from it to the particles lying above it ſhall be equal to the ſum of all the diſtances of thoſe which are below it. Therefore the ſituation of the point P is now determined, namely, at the common interſection of three planes perpendicular to each other. It is evident, that this point alone can have the condition required in reſpect of theſe three planes.

Motions continually deflected.

It ſtill remains to be determined whether the ſame condition will hold true for the point thus found, in reſpect to *any other* plane paſſing through it; that is, whether the ſum of all the perpendiculars on one ſide of *this fourth* plane is equal to the ſum of all the perpendiculars on the other ſide.

Let AGHB (fig. 22.), AXYB, and CDFE, be three planes interſecting each other perpendicularly in the point C; and let CIKL be any other plane, interſecting the firſt in the line CI, and the ſecond in the line CL. Let P be any particle of matter in the body or ſyſtem. Draw PM, PO, PR, perpendicular to the firſt three planes reſpectively, and let PR, when produced, meet the oblique plane in V; draw MN, ON, perpendicular to CB. They will meet in one point N. Then PMNO is a rectangular parallelogram. Alſo draw MQ perpendicular to CE, and therefore parallel to AB, and meeting CI in S. Draw SV; alſo draw ST perpendicular to VP. It is evident that SV is parallel to CL, and that STRQ and STPM are rectangles.

All the perpendiculars, ſuch as PR, on one ſide of the plane CDFE, being equal to all thoſe on the other ſide, they may be conſidered as compenſating each other; the one being conſidered as poſitive or additive quantities, the other as negative or ſubtractive. There is no difference between their ſums, and the ſum of both ſets may be called 0 or nothing. The ſame muſt be affirmed of all the perpendiculars PM, and of all the perpendiculars PO.

Every line, ſuch as RT, or its equal QS, is in a certain invariable ratio to its correſponding QC, or its equal PO. Therefore the poſitive lines RT are compenſated by the negative, and the ſum total is nothing.

Every line, ſuch as TV, is in a certain invariable ratio to its correſponding ST, or its equal PM, and therefore their ſum total is nothing.

Therefore the ſum of all the lines PV is nothing; but each is in an invariable ratio to a correſponding perpendicular from P on the oblique plane CIKL. Therefore the ſum of all the poſitive perpendiculars on this plane is equal to the ſum of all the negative perpendiculars, and the propoſition is demonſtrated, viz. that in every body, or ſyſtem of bodies, there is a point ſuch, that if a plane be paſſed through it *in any direction whatever*, the ſum of all the perpendiculars on one ſide of the plane is equal to the ſum of all the perpendiculars on the other ſide.

80. If A and B (fig. 23.) be the centres of poſition of two bodies, whoſe quantities of matter (or numbers of equal particles) are a and b, the centre C lies in the ſtraight line joining A and B, and AC : CB$=b$: a, or its diſtance from the centres of each are inverſely as their quantities of matter. For let αCβ be any plane

paſſing through C. Draw $A\alpha$, $B\beta$, perpendicular to this plane. Then we have $a \times A\alpha = b \times B\beta$, and $A\alpha : B\beta = b : a$, and, by ſimilarity of triangles, $CA : CB = b : a$.

If a third body D, whoſe quantity of matter is d, be added, the common centre of poſition E of the three bodies is in the ſtraight line DC, joining the centre D of the third body with the centre C of the other two, and $DE : EC = a + b : d$. For, paſſing the plane $\delta E \kappa$ through E, and drawing the perpendiculars $D\delta$, $C\kappa$, the ſum of the perpendiculars from D is $d \times D\delta$; and the ſum of the perpendiculars from A and B is $\overline{a+b} \times C\kappa$, and we have $d \times D\delta = \overline{a+b} \times C\kappa$; and therefore $DE : EC = a + b : d$.

In like manner, if a fourth body be added, the common centre is in the line joining the fourth with the centre of the other three, and its diſtance from this centre and from the fourth is inverſely as the quantities of matter; and ſo on for any number of bodies.

81. If all the particles of any ſyſtem be moving uniformly, in ſtraight lines, in any directions, and with any velocities whatever, the centre of the ſyſtem is either moving uniformly in a ſtraight line, or is at reſt.

For, let m be the number of particles in the ſyſtem. Suppoſe any particle to move uniformly in any direction. It is evident from the reaſoning in a former paragraph, that the motion of the common centre is the mth part of this motion, and is in the ſame direction. The ſame muſt be ſaid of every particle. Therefore the motion of the centre is the motion which is compounded of the mth part of the motion of each particle. And becauſe each of theſe was ſuppoſed to be uniform and rectilineal, the motion compounded of them all is alſo uniform and rectilineal; or it may happen that they will ſo compenſate each other that there will be no diagonal, and the common centre will remain at reſt.

COROLLARIES.

82. Cor. 1. *If the centres of any number of bodies move uniformly in ſtraight lines, whatever may have been the motions of each particle of each body, by rotation or otherwiſe, the motion of the common centre will be uniform and rectilineal.*

Cor. 2. *The quantity of motion of ſuch a ſyſtem is the ſum of the quantities of motion of each body, reduced to the direction of the centre's motion. And it is had by multiplying the quantity of matter in the ſyſtem by the velocity of the centre.*

Cor. 3. *The velocity of the centre is had by reducing the motion of each particle to the direction of the centre's motion, and then dividing the ſum of thoſe reduced motions by the quantity of matter in the ſyſtem.*

83. If on any two bodies of ſuch an aſſemblage equal and oppoſite quantities of matter be impreſſed, the motion of the centre of the whole is not at all affected by it. Becauſe the motion of the centre, ariſing from the motion of one of the bodies being compounded with the equal and oppoſite motion of the diagonal of the parallelogram, becomes a point; or theſe motions deſtroy one another, and therefore no change is effected on the motion of the centre.

PART II. OF MOVING FORCES.

84. HAVING in the former part conſidered the general doctrine of motion, which is the foundation of mechanical inveſtigations, we now proceed to treat of *moving forces* or *dynamics*, properly ſo called.

Object of dynamics.

It has been already obſerved, that dynamics includes the abſtract doctrine of moving forces, or the neceſſary reſults of the relations of our thought concerning motion, the immediate cauſes of motion, and its changes; and that from the changes obſerved, we infer agency in nature; and in theſe changes we are to diſcover what we know of their cauſes.

85. When we caſt our eyes around us, it cannot eſcape obſervation, that the changes which we perceive in the ſtate or condition of any body in reſpect of motion, are conſtantly and diſtinctly related to the ſituation and diſtance of other bodies. The motions of the moon, or of a ſtone projected through the air, have a palpable relation to the earth; the motions of the tides have alſo an obvious relation to the moon; and the motions of a piece of iron have a palpable dependence on a magnet. The vicinity of the one of theſe bodies ſeems to be the occaſion, at leaſt, of the motions of the other; and the cauſes of theſe motions have an evident connection with, or dependence on, the other body. Such dependences have been called the *mechanical relations* of bodies. They are indications of properties or diſtinguiſhing qualities. They accompany the bodies wherever they are, and are uſually conceived to be inherent in them. They at leaſt aſcertain and determine what is called the mechanical nature of bodies.

Mutual relation of bodies differently conſidered.

86. The mutual relation of bodies is differently conſidered according to the intereſt we may have in the phenomenon. The cauſe of the approach of the iron to the magnet is generally aſcribed to the magnet. It is ſaid to attract the iron. The approach of a ſtone to the earth is aſcribed to the ſtone. It is ſaid to tend to the earth. But it is probable that the procedure of nature is the ſame in both; that both bodies are affected alike, and that the property is diſtinctive of both. For in all caſes that have been obſerved, the indicating phenomenon is equally connected with both bodies; as in the caſe of magnetiſm the magnet and the iron approach each other; and an electrified body and another body near it approach each other. This property is therefore equally inherent in both bodies, between which there is a mutual attraction. But, according to ſome philoſophers, no ſuch mutual tendencies exiſt either in the one body or the other. The obſerved approaches or mutual ſeparations of bodies, or their attractions and repulſions, are ſuppoſed to depend on the extraneous action of an ethereal fluid.

Powers, &c.

87. Theſe qualities thus inherent in bodies, which conſtitute their mechanical relations, or the mechanical affections of matter, have been called *powers* or *forces*. The event which is indicated by their preſence, is conſidered

ſidered as the effect and mark of their agency. Thus the magnet is ſaid to *act* on the iron, the earth is ſaid to *act* on the ſtone which falls to its ſurface; and the iron and the ſtone are ſaid to act on the magnet and the earth. But all this, it muſt be obſerved, is figurative language. *Power*, *force*, and *action*, when uſed in their original ſtrict ſenſe, expreſs only the notions of the power, force and action of ſentient, active beings; and cannot be predicated of any thing but the exertions of ſuch beings; for ſuch beings only are agents. In ſtrict propriety, it is perhaps only the exerted influence of the mind on the body which ought to be called action. Language having begun among ſimple men, ſuch denominations were very properly given to their own exertions; becauſe to move a body they found it neceſſary to exert their force or power, or to act. But when the changes of motion, obſerved in the occurrence or vicinity of bodies, were attended to by ſpeculative men, and it was found that the phenomena greatly reſembled the reſults or effects when they exerted their own ſtrength, ſimilar terms were employed to expreſs theſe occurrences in nature. The old term was retained, in preference to the invention of a new language, to expreſs things which had ſo near a reſemblance. The danger of confounding things from the uſe of the ſame terms, was avoided from the differences in other circumſtances of the caſe. It is not, however, to be imagined, that they ſuppoſed inanimate bodies exerted force or ſtrength in the ſame way as living beings. But, in the progreſs of refinement, the word power or force came at laſt to be employed to expreſs *any efficiency whatever*; and hence the common expreſſions, the *force* of arguments, the *action* of motives, the *power* of an acid to diſſolve a metal, &c. It is to this idea of conveniency, that the uſe of the terms *attraction*, *repulſion*, *preſſure*, *impulſion*, as well as of the words power and force, which expreſs *efficiency* in general, is to be aſcribed. But theſe terms, excepting in thoſe caſes when they are applied to the exertions or actions of living beings, are metaphorical. On account, however, of the reſemblance between the phenomena and thoſe which are obſerved when we draw a thing toward us, puſh it from us, forcibly compreſs it, or kick it away, theſe different actions being analogous to attraction, repulſion, preſſure, and impulſion, theſe words are employed as terms of diſtinction. The action of the mind on the body is perhaps the only caſe of pure unfigurative action. But this action being always exerted with the view of effecting ſome change on external bodies, our attention is only directed to them. The inſtrument paſſes unnoticed; and hence it is ſaid that we act on the external body. The *real* action is only the firſt movement in a long ſucceſſion of events, and is only the remote cauſe of the intereſting event. In many caſes of mechanical phenomena, we find the reſemblance to ſuch actions to be very ſtrong. The following is of this deſcription. A ball is projected from a man's hand by the motion of his arm; and in the ſame way a ball is impelled by the unbending of a ſpring. In all circumſtances there is a reſemblance between theſe two events, excepting in the action of the mind on the corporeal organ. And, hence in general, becauſe the ultimate reſults of the mutual influence of bodies on each other have a ſtrong reſemblance to the ultimate reſults of our actions on bodies, no new or appropriate terms have been invented; but, as has been already obſerved, mankind have remained ſatisfied with the uſe of thoſe terms that are employed to expreſs their own actions, or the exertions of their own powers or forces.

Action of mechanical powers.

88. When power or force is ſpoken of as exiſting or reſiding in a body, and the effect is aſcribed to the exertion of this power, one body conſidered as poſſeſſing it, is ſaid to *act* on another. Thus a magnet is ſaid to act on a piece of iron; a billiard ball is ſaid to act on one which it ſtrikes. But if it be attempted to fix the attention on this action, independent both of the agent and the thing acted on, we ſhall find that there is no object of contemplation. The exertion or procedure of nature in effecting the change is kept out of view; and if we limit our attention to the action as a thing diſtinct from the agent, we ſhall find that it is not the action, ſtrictly ſpeaking, but the act, that is brought under conſideration. And in the ſame way, it is only in the effect produced that the action of a mechanical power can be conceived.

Change implied in action.

89. In the very nature of action ſome change is implied. Without producing ſome effect, a man is never ſaid to act. Thought is the act of the thinking principle; and the motion of the limb is the act of the mind on it. In mechanics too there is action only in ſo far as ſome mechanical effect is produced. For inſtance, to begin motion on a piece of ice, or to ſlide along it, we muſt act violently; we muſt exert force; and this force being exerted produces motion. In all caſes, the productions of motion are conceived as the exertions of force; but to continue the motion which has been begun along the ice, no exertion ſeems requiſite. Being conſcious of no exertion, we ought to infer that no force is neceſſary for the continuation of motion. It is not the production of any new effect, but the permanency or continuation of an effect already produced. Motion is indeed conſidered as the effect of ſome action; but there would be no effect or no change, if the body were not moving. Motion is not to be conſidered as an action, but the effect of an action.

Diviſion of mechanical forces.

90. Mechanical actions or forces have been divided into *preſſures* and *impulſions*. The idea of preſſure is very familiar; perhaps it enters into every diſtinct conception that we can form of a moving force, when the attention is endeavoured to be fixed on it. Changes of motion by the colliſion of moving bodies are produced by impulſion. Preſſures and impulſions are uſually conſidered as of different kinds, the actions or exertions of different powers. It is ſuppoſed that there is an eſſential difference between preſſure and impulſion. That we may obtain all the knowledge that theſe diſtinctions can give us, let us ſtate ſome examples of theſe kinds of forces, inſtead of attempting to define or deſcribe them.

Examples of preſſure,

Let us firſt take ſome examples of preſſure. Preſſure it is known is a moving force; for if a ball lying on the table be gently preſſed on one ſide, it moves toward the other ſide of the table. If it be followed with the finger, the preſſure being continued, its motion is continually increaſed. There is an acceleration of its motion. By preſſing in the ſame way on the handle of a common kitchen jack, the fly begins to move; and if the preſſure be continued on the handle, the motion of the fly becomes very rapid; and there

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is alſo a continual acceleration. Such motions as theſe are the effects of genuine preſſure. The unbending of a ſpring would urge the ball in the ſame way along the table, and would produce a continually accelerated motion; and a ſpring coiled up round the axis of the handle of the jack would, by uncoiling itſelf, urge round the fly with a ſimilar accelerated motion. By comparing the preſſure of the finger on the ball with the effects of the ſpring, we perceive diſtinctly the perfect ſimilarity. Theſe exertions or actions, or influences, are denoted by the word preſſure, which is derived from the moſt familiar inſtance of them.

The ſame motion may be produced in the ball or fly, by pulling the ball or machine by means of a thread having a weight ſuſpended to it. Both being motions accelerated in the ſame manner, the action of the thread on the ball or machine comes under the ſame denomination of preſſure. Weight is therefore conſidered as a preſſing power. And indeed the ſame compreſſion is felt from the real preſſure of a man on the ſhoulders and a load laid on them. But in the inſtance above, the weight acts by the intervention of the thread. By the preſſure of the weight it pulls at that part of the thread to which it is attached, this part pulls at the next by the force of coheſion; and this at a third, and ſo on, till the moſt remote pulls at the ball or machine. In this way elaſticity, weight, coheſion, and other forces, perform the office of a genuine power; and their reſult being always a motion beginning from nothing, and accelerating to any velocity by perceptible degrees, from this reſemblance we are led to give them one familiar name.

91. If the thread by which the weight is ſuſpended be cut, it falls with an accelerated motion. This alſo is aſcribed to ſome preſſing power which acts on the weight; and it is even conſidered as the cauſe of the body's weight, which word is a name by which this inſtance of preſſing power is diſtinguiſhed. Gravitation, therefore, comes under the denomination of preſſure. For the ſame reaſon the attractions and repulſions of the magnet, or of electric bodies, belong to this claſs of phenomena; for on bodies placed between them they produce actual compreſſions, as well as motions which are continually accelerated, in the ſame way as gravitation does. To all theſe powers, therefore, the deſcriptive name of *preſſures* may be given, although this name properly ſpeaking belongs to one of them only. This great claſs has been ſubdivided by ſome philoſophers into preſſions and ſolicitations. Gravity is conſidered as a ſolicitation *ab extra*, by which a body is urged downward. The forces of electricity and magnetiſm, with many other attractions and repulſions, are alſo called ſolicitations. But this claſſification ſeems to be of little uſe.

and of impulſion.

92. We have a familiar inſtance of impulſion in one ball ſtriking another, and putting it in motion. In this caſe the appearances are very different from the phenomena of preſſure. For the body that is ſtruck acquires in the inſtant of impulſe a ſenſible quantity of motion. But after the ſtroke this motion is neither accelerated nor retarded, unleſs by the action of ſome other force. The rapidity of the motion, it is obſerved depends on the previous velocity of the ſtriking ball. If for inſtance a clay ball, moving with any velocity, ſtrike another equal ball which is at reſt, the ball which is ſtruck moves with one half of the velocity of the other. It is farther obſerved that the ſtriking ball always loſes as much motion as the ball which is ſtruck gains. From this remarkable fact there ſeems to have ariſen an indiſtinct notion of a kind of transference of motion from one body to another. It is not ſaid that the one ball produces motion or cauſes it in the other, but it is ſaid to *communicate* motion to it; and the phenomenon is uſually termed the communication of motion. This, however, is a very inaccurate mode of expreſſion. We diſtinctly conceive the cauſe or communication of heat, the communication of ſaltneſs, of ſweetneſs, and of many other things; but we have no clear conception of part of the identical motion which exiſted in one body being transferred to another. From this, therefore, it appears that motion is not a thing which can exiſt independently, and is ſuſceptible of actual transference; but is a ſtate or condition of which bodies are ſuſceptible which may be produced in bodies, and which is the effect or characteriſtic of certain natural properties or powers.

Communication of motion.

The notion of the actual transference of ſomething formerly poſſeſſed by the ſtriking body, and now ſeparated from it, or transfuſed into the body which is ſtruck, has obtained ſupport from the remarkable circumſtance in the phenomenon, that a rapid motion requiring for its production the action of a preſſing power, continued for a ſenſible, and frequently a long time, is or ſeems to be effected inſtantaneouſly by impulſion. Here then we find room for the employment of metaphor, both in thought and language. We ſee the ſtriking body affect the body which is ſtruck. It poſſeſſes the power of impulſion, or of communicating motion, but it only poſſeſſes this power while it is itſelf in motion; and we therefore conclude that this power is the efficient diſtinguiſhing cauſe of its motion. Hence it has been called *inherent force*, the force inherent in a moving body, *vis inſita corpori moto*. This force is communicated to the body impelled, or transfuſed into it; the transference is inſtantaneous, and the body thus impelled continues its motion till it is changed by a new force. But if we attend ſcrupulouſly to thoſe feelings which have given riſe to this metaphorical conception, we ſhall find, that although at firſt ſight this train of obſervation ſeems very plauſible, we ſhould entertain very different notions. To begin the motion of ſliding on a ſmooth piece of ice, we are conſcious of exertion; but when the ice is very ſmooth, no exertion that we are conſcious of ſeems requiſite to continue the motion. No exertion of power is here neceſſary; and therefore we have no primitive feeling of power while we ſlide along. And indeed we cannot think of moving forward without effort otherwiſe than as a certain mode of exiſtence. It has however been imagined that thoſe who ſupport this opinion have in ſome way deduced it from their feelings. To move forward in walking, we muſt continue the exertion with which we began; and unleſs this power of walking be continually exerted, we muſt ſtop our progreſs. But this is inaccurate obſervation. In the action of walking there is much more than the continuance in progreſſive motion. It is the repeated and continued lifting the body up a ſmall height, and allowing it to come down again, and this repeated aſcent requires repeated exertion.

Impulſe ſaid to be infinitely greater than preſſure.

93. From the conſideration of the inſtantaneous production of rapid motion by impulſe, ſome diſtinguiſhed philoſophers have been led to ſuppoſe that the force or power of impulſion is not ſuſceptible of being compared with a preſſing power. It has been aſſerted that impulſe when compared with preſſure is infinitely great. But the ſimilarity of the ultimate reſults of impulſe and preſſure, have always led them to adopt a different view. There is no difference between the motion of two balls which move with equal rapidity, one of which deſcends from a height by the force of gravity, while the other has been ſtruck by another body. In this ſtruggle of the mind attached to preconceived opinions, and at the ſame time accommodating theſe opinions to obſerved phenomena, other ſingular forms of expreſſion have ariſen. Preſſure is conſidered as an effort to produce motion. And here we have another inſtance of metaphorical expreſſion as well as thought. The weight of a ball on the table is called a power; and this weight is continually *endeavouring* to move the ball downward. But theſe efforts being ineffectual, the power in this caſe is ſaid to be dead. It is called *vis mortua*, in contradiſtinction to the force of impulſion which is called a living power, *vis viva*. But this mode of expreſſion muſt appear very inaccurate, if we conſider the caſe of the impelling ball falling perpendicularly on the other ball lying on the table. No motion is induced by this impulſion; and if the table be conceived to be annihilated, the power of gravity becomes a *vis viva*.

Suppoſed proof.

To prove that impulſe is infinitely greater than preſſure, numerous familiar inſtances have been adduced by thoſe who ſupport this doctrine. A nail is driven with a moderate blow of a hammer, which would require a preſſure many hundred times greater than the impelling effort of the perſon who employs the hammer. A hard body may be ſhivered to pieces with a moderate blow, which would ſupport an inconceivable weight gradually applied. This prodigious ſuperiority in impulſion leaves it a difficult matter to account for the production of motion by means of preſſure; becauſe the motion of the hammer might have been acquired in conſequence of the continued preſſure of the carpenter's arm. It is conſidered as the aggregate of an infinite number of ſucceeding preſſures repeated in every inſtant of its continuance. The ſmallneſs of each effort is compenſated by their number.

There are not two kinds of mechanical force.

94. After all, it does not appear clear that there are two kinds of mechanical force which are eſſentially different in their nature. It is, indeed in a great meaſure given up by thoſe who ſupport the doctrine that impulſe is infinitely greater than preſſure: Some method might perhaps be found of explaining ſatisfactorily this remarkable difference between the two modes of producing motion. But there ſeems to be no conſiderable advantage in thus arranging the phenomenon under two diſtinct heads.

Impulſion the cauſe of motion,

95. The nature of the ſole moving force in nature has given riſe to much diſcuſſion among mechanicians, and produced no ſmall diverſity of opinion. According to ſome, all motion is the effect of preſſure; for when impulſe is conſidered as equivalent to the aggregate of an infinite number of preſſures, every preſſure, however ſmall, is ſuppoſed to be a moving force.

The ſole cauſe of motion, according to other philoſophers, is impulſion. Bodies are obſerved in motion; they impel others, and produce motion in them; and this production of motion is ſaid to be regulated by ſuch laws, that there is only one abſolute quantity of motion in the univerſe, which quantity remains invariably the ſame. Some portion of this motion, therefore, muſt be transferred or transfuſed when bodies come into colliſion with each other. But beſides, there are ſome caſes in which it is perfectly obvious that motion produces preſſure. Caſes, which are indeed both whimſical and complicated have been adduced by Euler, to ſhew that an action, in all reſpects ſimilar to preſſure, may be produced by motion. Such a caſe is the following. If two balls are connected by a thread, they may be ſtruck in ſuch a way, that they ſhall not only move forward, but at the ſame time alſo wheel round. When this happens, the thread by which they are connected is ſtretched. Since then, according to this reaſoning, motion is obſerved, and preſſure is produced by motion, it would be abſurd to ſuppoſe that preſſure is any thing elſe than the reſult of certain motions. The philoſophers who are attached to this doctrine of moving forces, proceed to account for thoſe preſſing powers or ſolicitations to motion which are obſerved in the acceleration of falling bodies, the phenomena of magnetiſm and electricity, and others of the ſame kind, where motion is induced on certain bodies which are in the vicinity of other bodies, or as it is expreſſed in common language by the action of other bodies at a diſtance. To ſay that a magnet cannot act on a piece of iron at a diſtance, is to ſay that it acts *where* it is not; which is not leſs abſurd than to ſay that it acts, *when* it is not. Euler aſſumed it is an axiom, *nihil movetur, niſi a contiguo et moto*.

The methods propoſed by theſe philoſophers to produce preſſure, are leſs ingenious and not more ſatisfactory than that adduced by Euler which was mentioned above; and indeed they do not ſeem to be very anxious about the manner in which theſe motions are produced. The phenomena of magnetiſm are induced, or a piece of iron is put in motion, when it is in the vicinity of a magnet, by a ſtream of fluid which iſſues from one pole of a magnet, paſſes in a circle round the magnet, and enters at the other pole. By this ſtream of fluid the iron is impelled, and brought to arrange itſelf in certain determined poſitions. In the ſame way all bodies are impelled in lines perpendicular to the ſurface of the earth by a ſtream of fluid which is in continual motion towards its centre. In the ſame way ſimilar phenomena are accounted for, and thus theſe motions are reduced to ſimple caſes of impulſion. But to ſay nothing worſe of this doctrine, it is not very compatible with the dictates of common ſenſe. It proceeds on the ſuppoſition that ſomething acts which we do not ſee; and of the exiſtence of which there is not the ſmalleſt proof.

or preſſure,

96. Preſſure, according to the opinion of others, is the only moving force in nature; but it is that kind of preſſure which has been termed ſolicitation, not what ariſes from the mutual contact of ſolid bodies. Gravitation is an inſtance of the kind of preſſure here alluded to. It is affirmed by theſe philoſophers, that there is no ſuch thing as contact on the inſtantaneous communication of motion by the real colliſion of bodies. It is ſaid that the particles of ſolid bodies exert very ſtrong

repulſions to a ſmall diſtance; and when they are brought by any motion ſufficiently near to another body, they exert a repulſive force, and are equally repelled by this body. Motion is thus produced in the one body, while it is diminiſhed in the other. It is then ſhown by ſcrupulouſly conſidering the ſtate of the bodies while the one advances, and the other retires, in what way they attain a common velocity, the quantity of motion before colliſion remaining the ſame, and the one body gaining exactly as much as the other loſes. Caſes alſo are adduced, of ſuch mutual action between bodies, where it is obvious they have never come into contact; but where the reſult is exactly the ſame as when the motion ſeemed to be inſtantaneouſly changed. And hence it is concluded that there is no ſuch thing as inſtantaneous communication, or transfuſion of motion by contact in colliſion or impulſe. All moving forces according to theſe philoſophers, are of that kind which have been named ſolicitations; ſuch as gravity is.

Exertions of mechanical forces named from their reſult.

97. Different names have been given to the exertions of mechanical forces, according to the reference that is made to the reſult. In wreſtling when my antagoniſt exerts his ſtrength to prevent being thrown down, and I am ſenſible of his exertion, I thus diſcover that he reſiſts. But if I oppoſe him only to prevent him throwing me, I am ſaid to reſiſt. If I ſtrike or endeavour to throw him, I am ſaid to act. The ſame diſtinction is applied to the exertion of mechanical powers. If, for inſtance one body A change the motion of another body B, the change in the motion of B may be conſidered either as the indication and meaſure of the power of A in producing motion, or as the indication and meaſure of the reſiſtance made by A in being brought to reſt, or having any change induced on its motion. The diſtinction which is here made is not in the thing itſelf, but exiſts only in the reference which we are diſpoſed to make of its effect, from other conſiderations. If a change of motion take place when one of the powers ceaſes to be exerted, it is conceived that this power has reſiſted. But this language is metaphorical. Reſiſtance, effort, endeavour, are all words which expreſs motion that relate to ſentient beings. There is perhaps no word preferable to the word *reaction*, to expreſs the mutual force which is obſerved in all the operations of nature which have been ſucceſsfully inveſtigated.

Suppoſed to depend on attraction and repulſion.

98. A difficulty has been ſtarted with regard to the opinion of thoſe who affirm that all mechanical phenomena are dependent on attracting and repelling forces; becauſe it is here ſuppoſed that bodies act on each other at a diſtance, and however ſmall this diſtance may be, this is conceived to be abſurd. It may however be obſerved, that the mutual approaches or receſſes of bodies may be aſcribed to tendencies to, or from each other. Without thinking of any intermediate connection between the iron and the magnet, we conceive the iron to be affected by the magnet; and if this be conceivable, it is not abſurd. Our knowledge of the eſſence or nature of matter is not ſuch as to render this tendency of the iron to the magnet impoſſible. We do not indeed ſee intuitively why the iron ſhould approach to the magnet; but this is by no means ſufficient to pronounce it impoſſible or inconſiſtent with the nature of matter. To ſuppoſe therefore in the production of motion, the impulſe of an inviſible fluid, of which we know not any thing, and of whoſe exiſtence there is no evidence, is a raſh and unwarrantable aſſumption. But farther, if it be true that bodies do not come into contact, even when one ball ſtrikes another, and drives it before it, the ſuppoſition of the exiſtence of this inviſible fluid will not aſſiſt us in ſolving the difficulty; for the ſame difficulty would occur in the action of any one particle of the fluid in the body. At any rate the production of motion without any obſerved contact, is more familiar to us than the production of motion by one body acting on another by impulſion. Every caſe of gravitation is an inſtance of this.

Attraction and repulſion explained.

99. In thoſe caſes where the exertions of any mechanical power are obſerved to be always directed toward any body, that body is ſaid to *attract*. Thus a boat is attracted toward a man when he pulls it toward him by means of a rope. This is a caſe of pure *attraction*. But when the other body always moves off, the body exhibiting this phenomenon is ſaid to repel; and it is a caſe of pure *repulſion* when a perſon puſhes any body from him. And becauſe there is a reſemblance to the reſults of real attraction and repulſion, the ſame terms are employed to expreſs the mechanical phenomena of nature. But that our conceptions may not be embarraſſed or rendered obſcure by the uſe of ſuch metaphorical expreſſions, it is requiſite to be careful not to allow theſe words to ſuggeſt to us any opinion about the manner in which mechanical forces produce their effects. If the opinion which is held of the exiſtence of an inviſible fluid on which mechanical action depends be well founded, it is obvious that there can be neither attraction nor repulſion in the univerſe.

Forces meaſurable quantities,

100. Forces are conceived as meaſurable quantities. Thus we conceive one man to poſſeſs double the ſtrength of another man, when we obſerve that he can reſiſt the combined efforts of two others. It is in this way that animal force is conceived as a quantity made up of its own parts and meaſured by them. This however ſeems not to be a very accurate conception. Our conception of one ſtrain being added to another is obſcure, although we have a diſtinct notion of their being combined. There are no words to expreſs the difference of theſe two notions in our minds; but we think that the ſame difference is perceived by others. We have a clear conception of the addition of two lines or two minutes; but our notions of two forces combined are indiſtinct; although it cannot be affirmed that two equal forces are not double of one of them. They are meaſured by the effects which they are known to produce.

and ſuch as are mechanical.

101. In the ſame way mechanical forces are conceived as meaſurable by their effects, and thus become the ſubjects of mathematical diſcuſſion. We ſpeak of the proportions of magnetiſm, electricity &c. and even of the proportion of gravity to magnetiſm. Theſe however, conſidered in themſelves, are quite diſſimilar, and do not admit of any proportion; but ſome of their effects are meaſurable, and theſe aſſumed meaſures being quantities of the ſame kind are ſuſceptible of compariſon. The acceleration of motion in a falling body, is one of the effects of gravity; magnetiſm accelerates the motion of a piece of iron; and theſe two accelerations may be compared together. But becauſe none of the meaſurable effects of magnetiſm with which we are

acquainted, are of the ſame kind with any of the effects of heat, magnetiſm and heat are not ſuſceptible of compariſon.

Compariſon of the effects of gravity.

When it is ſaid that the gravitation of the moon is the 3600th part of the gravitation at the ſea-ſhore, it is meant that the fall of a ſtone in a ſecond is 3600 times greater than the fall of the moon in the ſame time. But to expreſs the proportion of the tendency of gravitation more purely, if a ſtone hung on the ſpring of a ſteelyard, draw out the rod of the ſteelyard to the mark 3600, the ſame ſtone carried up to the diſtance of the moon will draw it out only to the mark one. And if the ſtone at the ſea-ſhore draw out the rod to any mark, it will require 3600 ſuch ſtones to draw the rod out to the ſame mark at the diſtance of the moon. Now, it is not in conſequence of an immediate perception of the proportion of gravitation at the moon to that at the ſurface of the earth that ſuch an aſſertion is made. It is becauſe theſe motions being conſidered as its effects in ſuch ſituations, and being magnitudes of the ſame kind, are ſuſceptible of compariſon, and have a proportion which can be determined by obſervation. And although the proportions of the cauſes or forces are ſpoken of, yet it is only the proportions of the effects which come under contemplation.

Meaſures muſt be the ſame in kind and degree.

102. In order that theſe aſſumed meaſures may be accurate, they muſt be always connected with the magnitudes which they are employed to meaſure; and the connection muſt be of that kind, that the degrees of the one muſt change in the ſame manner with the degrees of the other. The ſame thing muſt alſo be known of the meaſure which is employed; the preciſe and conſtant relation muſt be ſeen. But how is this to be accompliſhed? Force as a ſeparate exiſtence is not a perceptible object. We do not perceive its proportions, ſo as to be able to aſcertain that they are the ſame with the proportions of the meaſures. On the contrary, the very exiſtence of this force is inferred from obſervation of the acceleration, and its degree is alſo an inference from the obſerved extent or magnitude of the acceleration. The meaſures which are thus aſſumed are therefore neceſſarily connected with the magnitudes, and their proportions are the ſame; the one is an inference from the other both in kind and degree.

Dynamics a demonſtrative ſcience.

103. It now appears that this ſubject is ſuſceptible of mathematical inveſtigation. After having ſelected our meaſures, and obſerving certain mathematical relations of thoſe meaſures, every inference deduced from the mathematical relations of the proportions of thoſe repreſentations is true of the proportions of the motions, and therefore it is alſo true of the proportions of the forces. Thus then Dynamics may be reckoned a demonſtrative ſcience.

Forces differ in direction.

104. Moving forces are conſidered as differing alſo in kind, that is, in direction. The direction of the obſerved change of motion is aſſigned to the force; which is not only the indication, but alſo the meaſure of the changing force. This force is called an accelerating, retarding, or deflecting force, according as it is obſerved, that the motion is accelerated, retarded, or deflected. And from theſe terms it muſt appear, that we have no knowledge of the forces different from our knowledge of the effects. They are either deſcriptive of the effects, or they have a reference to the ſubſtances in which the forces are ſuppoſed to be inherent. Thus of the firſt kind are the terms *accelerating*, *attractive*, or *repulſive* forces; of the ſecond, are the terms *magnetiſm*, *electricity*, &c.

Of the Laws of Motion.

105. Such then being our notions of mechanical forces, of the cauſes of the production of motion and its changes, there are certain reſults, which by the conſtitution of the human mind, neceſſarily ariſe from the relations of theſe ideas. Theſe reſults are laws of human judgment, independent of all experience of external nature. Some of theſe laws may be intuitive, preſenting themſelves to the mind as ſoon as the ideas which they involve are preſented to it. Theſe may be called axioms. Others may be as neceſſary reſults from the relations of theſe notions, are leſs obvious, and may require a proceſs of reaſoning to eſtabliſh their truth.

Of theſe laws there are three, which were firſt diſtinctly propoſed by Sir Iſaac Newton. Theſe may be conſidered as the firſt principles of all diſcuſſions in mechanical philoſophy, give a ſufficient foundation for all the doctrines of Dynamics, and to theſe principles we may refer for the elucidation of all the mechanical phenomena of nature.

Firſt Law of Motion.

106. *Every body continues in a ſtate of reſt, or of uniform rectilineal motion, unleſs it is affected by ſome mechanical force.*

Importance of this propoſition.

On the truth of this propoſition the whole of mechanical philoſophy chiefly depends. But with regard to its truth and the foundation on which it reſts, the opinions of philoſophers are very different. In general theſe opinions are obſcure and unſatisfactory; and, as is uſual, they influence the diſcuſſions of thoſe who hold them in all their inveſtigations.

Reſt ſuppoſed to be the natural condition of body.

107. It is not only the popular opinion that a ſtate of reſt is the natural ſtate of body, and that motion is ſomething foreign to it, but the ſame opinion has been ſupported by many philoſophers. They allow that matter unleſs it is acted on by ſome moving force will remain at reſt; and nothing ſeems neceſſary for matter to remain where it is, but its continuing to exiſt. But the caſe is widely different, according to theſe philoſophers, with reſpect to matter in motion. For here the relations of the body to other things are continually changing; and as there is the continual production of an effect, the continual agency of a changing cauſe is neceſſary. This metaphyſical argument, it is ſaid, is fully confirmed by the moſt familiar obſervation. All motions, whatever may have been their violence, terminate in reſt, and for their continuance the continual exertion of ſome force is neceſſary.

Continual exertion of force neceſſary in motion.

108. It is affirmed by theſe philoſophers, that the continual action of the moving cauſe is eſſentially requiſite for the duration of the motion. But their opinions of the nature of this cauſe are not uniform. According to ſome, all the motions in the univerſe are produced and continued by the direct agency of the Deity himſelf. By others all the motions and changes of every particle of matter are aſcribcd to a ſort of mind which is inherent in it. This is called an *elemental mind.* It is the ſame as the φυσις and the ὁσπεϱ ψυχη of Ariſtotle. Every thing, according to theſe philoſophers,

phers, which moves, is mind, and every thing which is moved is body. But this elemental mind is only known and characterized by the effects which are aſcribed to its action; and theſe are obſerved in the motions or changes which are produced. Theſe, we learn from uniform experience, are regulated by laws equally preciſe with the laws of mathematical truth. But there is nothing which indicates any thing like intention or purpoſe; none of the marks or characters by which mind was brought firſt into view. They reſemble the effects produced by the exertions of corporeal force; and hence the word *force* has been applied to expreſs the cauſes of motion.

No body is in abſolute reſt.

109. A ſtate of reſt, it has been ſuppoſed, is the natural ſtate of matter. But it does not appear that the continued action of ſome cauſe is neceſſary for continuing matter in motion. Experience gives us no authority for ſuppoſing that the natural condition of matter is a ſtate of reſt. It cannot be affirmed of any body whatever that it has ever been ſeen in abſolute reſt. All the parts of the planetary ſyſtem are in motion; and even the ſun himſelf with his attendant planets is carried in a certain direction with a great velocity. There is no unqueſtionable evidence that any of the ſtars are abſolutely fixed; and many of them, it has been aſcertained by obſervation, are in motion. Reſt, therefore being ſo rare a condition of matter, no experience which we have, ſupports the notion that this is its natural condition. This opinion ſeems to be derived from our own experiments on matter. To continue the motion of a body, we find that the continued action of ſome moving force is neceſſary, otherwiſe the motion becomes gradually ſlower, and at laſt terminates in reſt. Since then we ſee that our own exertions are conſtantly neceſſary in the production of motion, and eſpecially in thoſe caſes where we are intereſted; we are thus induced to aſcribe to matter ſomething that is naturally quieſcent and inert, and even ſomething that is ſluggiſh and averſe from motion. But this is an erroneous conception, which is ſuggeſted to our thoughts from the imperfection of language. We aſcribe animation to matter to give it motion, and endow it with a kind of moral character in order to explain the phenomena of motion.

Matter has aptitude to reſt.

110. But more accurate and more extended obſervation leads us to conclude that matter has no peculiar aptitude to a ſtate of reſt. Every obſerved retardation has a diſtinct reference to external circumſtances. Wherever there is a diminution of motion, it is invariably accompanied by the removal of obſtacles; as in the caſe when a ball moves through ſand, or air, or water. The diminution of motion is alſo owing to oppoſite motions which are deſtroyed. And it is found that the more theſe obſtacles are kept out of the way, the leſs is the diminution of motion. The vibration of a pendulum in water ſoon ceaſes; it continues longer in air; and much longer in the exhauſted receiver. The concluſion then from theſe obſervations is, that if all obſtacles could be completely removed, motion would continue for ever. This concluſion is ſtrongly ſupported by the motions of the heavenly bodies. Theſe motions, ſo far as we know, are retarded by no obſtacles; and accordingly they have been obſerved to retain them without perceptible diminution for thouſands of years.

This is denied by others.

111. The inactivity of matter has been denied by other philoſophers. According to them it is eſſentially active, and continually undergoing changes in its condition. Some traces of this doctrine are to be found in the writings of ſome of the ancient philoſophers; but it was reduced to a ſyſtematic form by Leibnitz. According to this philoſopher, every particle of matter is endowed with a principle of individuality. This he calls a *monad*, which is ſuppoſed to have a kind of perception of its place in the univerſe, and of its relation to all other parts of the univerſe. This monad too is ſuppoſed to act on the particle of matter in the ſame way as the ſoul acts on the body. The motion of the material particle is modified by the monad, and thus are produced, according however to unalterable laws, all the obſerved modifications of motion. And thus matter, or the particles of matter, are continually active and continually changing their ſituation. No information in any way uſeful can be obtained from this fanciful hypotheſis. It is not unlike the ſyſtem of elemental minds. And ſhould its exiſtence be admitted, it would not any more than the actions of animals invalidate the general propoſition which is conſidered as the fundamental law of motion. The powers of the monads or of the elemental minds are ſuppoſed to be the cauſes of all the changes; but the particle of matter itſelf is ſubject to the law, and any change of motion which it exhibits is aſcribed to the exertion of the monad.

This law deduced from the want of a determining cauſe,

112. By another ſet of philoſophers, this law of motion is deduced from the want of a determining cauſe. At the head of this ſect is Sir Iſaac Newton, who maintains the doctrine affirmed in the propoſition. But theſe philoſophers are not uniform in their opinion of the foundation on which it reſts. It is aſſerted by ſome that it is a kind of neceſſary truth which ariſes from the nature of the thing. If, for inſtance, a body in a ſtate of reſt, and if it be aſſerted that it will not remain at reſt, it muſt move in ſome direction; and if it be in motion in any direction, and with any velocity, and do not continue its equable, rectilineal motion, it muſt be either accelerated or retarded; it muſt either turn to one ſide, or to ſome other ſide. The event, whatever it be, is individual and determinate; but no cauſe which can determine it being ſuppoſed, the determination cannot take place, and no change with reſpect to motion will happen in the condition of the body. It will either remain at reſt, or perſevere in its rectilineal and equable motion. But to this argument of ſufficient reaſon, as it has been called, conſiderable objections may be made. In the immenſity and perfect uniformity of time and ſpace, there is no determining cauſe why the viſible univerſe ſhould exiſt in one place rather than in another, or at this time rather than at another. It is eſſentially neceſſary that there ſhould be a cauſe of determination; for a determination may be without a cauſe, as well as a motion without a cauſe.

and from experience,

113. Other philoſophers deduce this law of motion from experience. They conſider it merely as an experimental truth, of the univerſality of which there are innumerable proofs. When a ſtone is thrown from the hand, it is preſſed forward, and when the hand has the greateſt velocity that we can give it, the ſtone is let go, and it continues in that ſtate of motion which it gradually acquired along with the hand. A ſtone may be thrown much farther by means of a ſling, becauſe with

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a very moderate motion of the hand, the ſtone being whirled round acquires a very great velocity, and when it is let go, it continues its rapid motion. We have a ſimilar illuſtration in the caſe of an arrow ſhot from a bow. The ſtring which preſſes hard on the notch of the arrow carries it forward with an accelerated motion as it becomes a ſtraight line by the unbending of the bow; and there being nothing to check the arrow, it flies off. In theſe ſimple caſes of perſeverance in a ſtate of motion the procedure of nature is eaſily traced; it is perceived almoſt intuitively. In many other phenomena it is not leſs diſtinct, although ſomewhat more complicated. A man can ſtand on the ſaddle of a horſe at a gallop, and ſtep from it to the back of another horſe that gallops along with him at the ſame rate; and this he ſeems to do with the ſame eaſe as if the horſes were ſtanding ſtill. The man is carried along with the ſame velocity as the horſe which gallops under him, and he retains the ſame velocity while he ſteps from the back of one horſe to that of the other. But if the horſe to which he ſteps were ſtanding ſtill, he would fly over his head, becauſe he is carried forward with the velocity of the galloping horſe; or if he ſtepped from the back of a horſe ſtanding ſtill to that of one at a gallop, he would be left behind; becauſe he has not acquired the velocity of the galloping horſe. In the ſame way, a man toſſes oranges from one hand to the other while he is carried forward with the motion of a horſe at a gallop, or while he ſwings on the ſlack-wire. In both caſes the oranges have the ſame motion as the man, and while they are in the air are moving forward with the ſame velocity, ſo that they drop into the hand at a conſiderable diſtance from the place in which they were thrown from the other hand. While a ſhip ſails forward with a rapid motion a ball dropped from the maſt head falls at the foot of the maſt; for it retains the motion which it had previous to its being dropped, and follows the maſt during the whole time of its fall.

in caſes of motion

and of reſt.

114. Familiar inſtances may alſo be given of a body in a ſtate of reſt. A veſſel filled with water drawn ſuddenly along the floor, leaves the water behind, which is daſhed over the poſterior ſide of the veſſel; and when a boat or coach is ſuddenly dragged forward, the perſons in it find themſelves ſtrike againſt the hinder part of the carriage or boat; or rather it ſhould be ſaid the carriage ſtrikes on them, for it ſooner acquires motion from the action of the force applied. A ball diſcharged from a cannon will paſs through a wall and move onward; but the wall remains behind.

But common experience inſufficient.

115. Common experience is perhaps inſufficient for eſtabliſhing the truth of this fundamental propoſition. It muſt be granted, that we have never ſeen a body either at reſt, or in uniform rectilineal motion; yet this ſeems neceſſary before it can be ſaid that the propoſition is experimentally eſtabliſhed. What is ſuppoſed in our experiments to be putting a body, formerly at reſt, into motion, is in fact only producing a change of a very rapid motion—a motion not leſs than 90,000 feet per ſecond.

Other proof neceſſary.

116. For the purpoſe of obtaining ſuch experimental proof of the truth of this propoſition, it will be neceſſary to reſort to other obſervations. The relative motions of bodies, which are the differences of their abſolute motions, only can be meaſured. We cannot meaſure their abſolute motions. If then it can be ſhown by experiment that bodies have equal tendencies to reſiſt the augmentation and diminution of their relative motions, they thus have equal tendencies to reſiſt the augmentation or diminution of their abſolute motions.

Let A and B two bodies be put into ſuch a ſituation, that they cannot perſevere in their relative motions. The change which we obſerve produced on A is the effect and meaſure of the tendency of B to perſevere in its former ſtate. From the proportion of theſe changes therefore we derive the proportion of their tendencies to remain in their former condition. This will be illuſtrated by the following experiment which ſhould be made at noon.

117. Let the body moving at the rate of three feet per ſecond to the weſtward, ſtrike the equal body B which is apparently at reſt. Different caſes of the reſults of the changes thus produced may be ſuppoſed.

1ſt. Let A impel B forward without having its own velocity at all diminiſhed. From this reſult it appears that B ſhows no tendency to maintain its motion unchanged, but that A retains its motion without diminution.

2d. Suppoſe that A ſtops, and that B remains at reſt. This caſe ſhows that A does not reſiſt a diminution of motion, and that the motion of B is not changed.

3d. Let it be ſuppoſed that both move weſtward at the rate of one foot per ſecond. There is in this caſe a diminution of the velocity in A, equal to two feet per ſecond. This then is to be conſidered as the effect and meaſure of the tendency of B to maintain its velocity unaugmented. B has received an augmentation of one foot per ſecond in its velocity. From this change it appears that the tendency is but half of the former; and the reſult ſhows that the reſiſtance to a diminution of velocity is only equal to one half of the reſiſtance to augmentation; and perhaps equal only to one quarter, ſince the change on B has effected a double change on A.

4th. Let it be ſuppoſed that both bodies move forward with the velocity of one and a half feet per ſecond. In this caſe it is obvious that the tendencies of the two bodies to maintain their ſtates unchanged are equal.

5th, But ſuppoſe that $A = 2B$, and that the velocity of both after colliſion is equal to two feet per ſecond. The body B has then received an addition of two feet per ſecond to its former velocity; and this is the effect and meaſure of the whole tendency of A to preſerve its motion undiminiſhed. One half of this change on B meaſures the perſevering tendency of one half of A; but it is ſuppoſed that A which formerly moved with the the apparent or relative velocity three, now moves with the velocity two, and thus has loſt the velocity of one foot per ſecond. Therefore each half of A has loſt this velocity; and the whole loſs of motion is two. This then is the meaſure of the tendency of B to maintain its former ſtate unaugmented; and it is the ſame with the meaſure of the tendency of A to preſerve its former ſtate undiminiſhed. From ſuch a reſult therefore the concluſion would be that bodies have equal tendencies to maintain their former ſtates of motion unaugmented and undiminiſhed.

The ſuppoſitions made above in the 4th and 5th caſes are the reſult of all the experiments which have been made; and in all the changes of motion which are produced by the mutual action of bodies on impulſion, this is the regulating law. To this there is no exception. And thus it appears that there exiſts in bodies no preferable tendency to reſt. No fact can be adduced which ſhould lead us to ſuppoſe that a motion having once begun ſhould ſuffer any diminution without the intervening action of ſome changing cauſe.

This proof imperfect.

118. It muſt, however, be obſerved that this is a very imperfect way of eſtabliſhing the firſt law of motion. It is inapplicable to thoſe caſes where experiment cannot be made; and at beſt it is ſubject to all the inaccuracy of the beſt managed experiments. If this propoſition be examined by means of the general principles which have been adopted in the article PHILOSOPHY, (which ſee) an accurate deciſion of this queſtion may be given. Theſe principles, which are the foundation of all our knowledge, ſhew that this propoſition is an axiom or intuitive conſequence of the relations of thoſe ideas which we have of motion, of its changes, and of their cauſes.

Exiſtence of forces inferences from motion.

119. Powers or forces, it has been ſhewn, are not the immediate objects of our perceptions. Their exiſtence, kind, and degree, are inferences from the motions which we obſerve. And hence it follows, that when no change of motion is obſerved, no ſuch inference is made; no force or power is ſuppoſed to act. But when any change of motion is obſerved, the inference is made; a power or force is ſuppoſed to have acted. By a ſimilar concluſion, it is ſaid, that when no change of motion is ſuppoſed, no force is thought of or ſuppoſed; and whenever a change of motion is ſuppoſed, it always implies a changing force. On the other hand, when the action of a changing force is ſuppoſed, the change of motion is alſo ſuppoſed; the action of this force and the change of motion being the ſame thing. The mind does not admit the idea of the action, without at the ſame time thinking of the indication of the action, and this indication is the change of motion. And in the ſame way, when we do not think of the changing force, or do not ſuppoſe the action of a changing force, we ſuppoſe, although it be not expreſſed in terms, that there is no indication of this changing force; that there is no change. If, therefore, it be ſuppoſed that no mechanical force acts on a body, we ſuppoſe in fact that the body remains in its former condition with reſpect to motion. And if it be ſuppoſed that nothing accelerates or retards, or deflects the motion, it is conceived as neither accelerated nor retarded, nor deflected. Hence it follows, that we ſuppoſe the body to continue in its former ſtate of reſt or motion, unleſs we ſuppoſe that it is changed by ſome mechanical force.

This law a neceſſary truth.

120. This propoſition then does not depend on the properties of body as a matter of experience or contingency. It is to us a neceſſary truth. It is not ſo much any circumſtances with regard to body that are expreſſed in the propoſition, as the operations of the mind in conſidering theſe circumſtances. The truth of the propoſition will not be invalidated by taking into view, that it may be eſſential to move in ſome particular direction; that it may be eſſential to body to ſtop when the moving cauſe ceaſes to act; or gradually to diminiſh its motion, and at laſt to come to reſt. The circumſtances in the nature of body which render thoſe modifications eſſentially neceſſary, are the cauſes of thoſe modifications; and they are to be conſidered as changing forces.

If we ſhould ſuppoſe that body of its own nature is capable of producing a change in its condition, this change muſt be effected according to ſome law which characterizes the nature of body. But the knowledge of this law can be obtained only by obſerving the deviations from uniform rectilineal motion. It then becomes indifferent whether external cauſes operate thoſe changes, or they depend on the nature of the thing; for in conſidering the various motions of bodies, we muſt firſt conſider the nature of matter as one of its mechanical affections which operates in every inſtance; and this brings us back to the law contained in the propoſition. This is rendered more certain by reflecting, that the external cauſes, ſuch for inſtance are gravity and magnetiſm, which are acknowledged to operate changes of motion, are not leſs unknown to us than this eſſential property of matter. They are, like it, only inferences from the phenomena.

Inadequate notions ſuggeſted by inaccurate expreſſions.

121. Many philoſophers, among which number may be included Newton himſelf, have introduced modes of expreſſion, which ſuggeſt inadequate notions, and ſuch as are incompatible with the doctrine of the propoſition; for although they allow that reſt is the natural condition of body, and that force is neceſſary for the continuation of motion, yet they ſpeak of a *power* or *force* reſiding in a moving body by which it perſeveres in its motion. This has been called the *vis inſita*, or the *inherent force* of a moving body. Now if the motion be ſuppoſed to be continued in conſequence of a force, that force muſt be ſuppoſed to be exerted, and it is ſuppoſed that if it were not exerted the motion would ceaſe. The propoſition, therefore, muſt be falſe. To obviate this objection it is indeed ſometimes ſaid, that the body continues in uniform rectilineal motion, unleſs it is acted on by ſome external cauſe. This mode of expreſſion, however, ſubjects us to the impropriety of aſſerting that gravity, electricity, and other mechanical forces, are external to the bodies on which they are ſuppoſed to act and to put in motion. Every thing which produces a change of motion is very properly called a force; and when a change of motion is obſerved, the action of ſuch a force is very properly inferred. But to give the ſame name to what has not this property of producing a change, and to infer the action of a force when no change is obſerved, is not a very accurate or conſiſtent expreſſion. This error has ariſen from the uſe of analogical language in philoſophical diſcuſſions.

Motion not a continued exertion, but an effect.

122. But motion is not, as philoſophers have imagined, the continual production of an effect. We can conceive there is ſuch a thing as a moving cauſe, to which the name of *force* has been given. This produces motion, and the character of motion in body, which is a continual change of place. Motion is the effect of an action; and previous to the commencement of the motion, this action is equally incomplete as it is the minute after. The immediate effect of a moving force is a determination to motion, which if not obſtructed by ſome cauſe would go on for ever. In this determination only the condition of the body differs from a ſtate of reſt. Motion then is a condition or mode of exiſtence, which no more requires the continued agency of the moving cauſe than colour or figure. Some mechanical cauſe is required to change this condition into the ſtate or condition of reſt. When a

moving

moving body is brought to reſt, ſome cauſe of this ceſſation of motion never fails to occur to the mind. A cauſe is no leſs neceſſary to ſtop the motion of body than it is to produce it. Now this cauſe muſt either reſide in the body or be external to it. If it reſide in the body, then it poſſeſſes a ſelf-determining power or force, by which it may be able to ſtop its own motion as well as to produce it.

Is not the effect of inherent force.

123. Taking this view of the ſubject, the opinion of a force reſiding in a moving body by which its motion is continued muſt be given up; and the remarkable difference between a body in a ſtate of motion and a ſtate of reſt muſt be explained on other principles. Motion, it cannot be doubted, is neceſſary in the impelling body to permit the forces which are inherent in one or both bodies to continue the preſſure long enough for the production of ſenſible motion. But whether bodies be in the condition of motion or reſt, theſe forces are inherent in them. If we reflect on the motions that are involved in the general conception of one body being impelled and put in motion by another, we ſhall ſee that there is nothing individual transferred from the one to the other. Before colliſion took place the determination to motion exiſted only in the impelling body. After colliſion, both bodies poſſeſſed this condition or determination. But we have no conception, we can form no notion of the thing transferred.

Vis inertiæ an indefinite term.

124. An expreſſion not leſs vague and indefinite is alſo very common among mechanical philoſophers. This is the phraſe *inertia*, or *vis inertiæ*. This expreſſion, which was introduced by Kepler, ſeems to have been generally employed by him as well as by Newton to expreſs the fact of the perſeverance of body in a ſtate of motion or reſt. Sometimes, however, it has been employed by theſe philoſophers to expreſs ſomething like indifference to motion or reſt; and this is ſuppoſed to be manifeſted by body requiring the ſame quantity of force to make an augmentation of its motion, as is neceſſary to produce an equal diminution of it. To ſuppoſe reſiſtance from a body at reſt ſeems to be in direct contradiction to the common uſe of the word *force;* and yet this expreſſion *vis inertiæ* is very common. It is not leſs abſurd to ſay that a body remains in the condition of reſt by the exertion of a *vis inertiæ*, than to affirm that it maintains itſelf in a ſtate of motion by the exertion of an inherent force. Such expreſſions, which are metaphorical, ſhould be carefully avoided, becauſe they are apt to lead to miſconception of the procedure of nature.

Reſiſtance of matter a miſconception.

125. In the phenomena of motion the force employed always produces its complete effect. No reſiſtance whatever is obſerved. When one man throws down another, and he finds that no more force has been required than to throw down a ſimilar and equal maſs of inanimate matter, he concludes that no reſiſtance has been made; but if more force be neceſſary, the concluſion is that reſiſtance has been made. When, therefore, the exerted force produces its full effect, there is no ſuch thing as reſiſtance properly ſo called. It is therefore miſconceiving the mode in which mechanical forces operate in the colliſion of bodies, to ſay that there is any reſiſtance. For there is no more in theſe caſes than in other natural changes of condition. It may be obſerved, that theſe terms *inherent force*, and *inertia*, may be employed for the purpoſe of abbreviating language, provided they are uſed only for expreſſing either the ſimple fact of perſevering in the former ſtate, or the neceſſity of a determinate force to produce a change on that ſtate, being careful to avoid all thought of reſiſtance.

Deviations from uniform motion indications of force.

126. Thus it appears that deviations from uniform motions are the only indications of the exiſtence and agency of mechanical forces. This indication is ſimply change of place; and it can only indicate what is very ſimple, ſomething competent to the production of the obſerved motion. The ſame thing is indicated by two ſimilar changes of motion. A compaſs needle in a ſtate of reſt, can be moved ſome degrees by means of the finger, a magnet, an electrified body, or by the unbending of a ſpring, &c. in all which caſes the indication is preciſely the ſame; and therefore the thing indicated muſt alſo be the ſame. This is the intenſity and direction of ſome moving power. The circumſtances of reſemblance by which the affections of matter are to be characterized are impulſiveneſs, intenſity, and direction. This leads us to conſider the ſecond law of motion.

Second Law of Motion.

Every change of motion is proportional to the force impreſſed, and it is made in the direction of that force.

Is an identical propoſition;

127. This law of motion alſo may almoſt be conſidered as an identical propoſition. It is equivalent to ſaying that the changing force is to be meaſured by the change produced, and the direction of this force is the direction of the change. Conſidering the force only in the ſenſe of its being the cauſe of motion, and withdrawing the attention from the manner or form of its exertion, there can be no doubt of this. In whatever way a body is put in motion, whether by the expanſive force of the air, by the unbending of a ſpring, or by any ſimilar preſſure, when it moves off in the ſame direction, and with the ſame velocity, the force or the exertion of the force is conſidered as the ſame. Even when it is put in motion by inſtantaneous percuſſion from a ſmart ſtroke, although in this caſe the manner of the effect being produced is eſſentially different from the other caſes, we cannot conceive the propelling force, as ſuch, but as preciſely one and the ſame. The expreſſion of this law of motion by Newton is equivalent to ſaying, "that the changes of motion are taken as the meaſures of the changing forces, and the direction of the change is taken as the indication of the direction of the forces; for it cannot be ſaid that it is a deduction from the acknowledged principle, that effects are proportional to their cauſes. This law is not affirmed from the proportion of the forces and the proportion of the changes, and that theſe proportions are the ſame, having been obſerved; and that this univerſally holds in nature. For forces are not objects of obſervation, and we do not know their proportions. In this way it would be eſtabliſhed as a phyſical law, as indeed it is ſo in fact. But according to the definition of the term, this does not eſtabliſh it as a law of motion; or as a law of human thought, the reſult of the relations of our ideas. Philoſophers having attempted to prove this as a matter of obſervation, have produced great diverſity of opinion in the mode of eſtimating forces. A bullet, it is well known, which moves with double velocity, penetrates four times as far. This is

but not deduced from the proportion of the forces.

confirmed by other ſimilar facts; and to generate this double velocity in the bullet, it has been obſerved by philoſophers four times the force is expended, four times as much powder is required. This is the invariable reſult; and in caſes of this kind, it would appear that the ratio of the forces employed has been very accurately aſcertained. The concluſion therefore is, that moving forces are not proportional to the velocities produced, but to the ſquares of the velocities. This is ſtrongly confirmed by obſerving that moving bodies ſeem to poſſeſs forces in this very proportion, and to produce effects in this proportion; when, for inſtance, the velocity is only twice as great, they penetrate four times as deep.

Incompatible with the velocity being proportional to the force.

128. If this mode of eſtimation be juſt, it is irreconcileable with the conceſſion of thoſe, who admit that the velocity is proportional to the force impreſſed, in thoſe caſes where no previous obſervation can be had of the ratio of the forces, and of its equality to the ratio of the velocities. Such a caſe is the force of gravity, which theſe philoſophers always meaſure by its accelerating power, or the velocity generated in a given time. This muſt be granted; for there are caſes in which the force can be meaſured by the actual preſſure which it exerts. Thus a ſpring ſteelyard can be conſtructed, the rod of which is divided by hanging on ſucceſſively a number of perfectly equal weights. In the different ſtates of tenſion of the ſpring, its elaſticity is proportional to the preſſures of gravity which it balances. If it be found, that at Quito in Peru, a weight will pull out the rod to the mark 312, and that the ſame weight at Spitzbergen draws it out to 313, it ſeems to be a fair inference to ſay, that the preſſure of gravity at Quito is to its preſſure at Spitzbergen as 312 to 313; and this is affirmed on the authority of effects being proportional to their cauſes. Such caſes, however, are very rare; for it is ſeldom, that the whole of a natural power, accurately meaſured in ſome other way, is employed in producing the obſerved motion. Part of it is generally otherwiſe expended, and therefore it frequently happens that the motions are not in the proportion with the ſuppoſed forces. And allowing that this could be done with accuracy, it would only be the proof of a general law or fact: but theſe philoſophers attempt to eſtabliſh it as an abſtract truth.

129. It ſeems to be conſidered by Sir Iſaac Newton only as a phyſical law. And in this ſenſe good arguments are not wanting. A ball which moves with a double, triple, or quadruple velocity, generates by impulſe in another, a double, triple, or quadruple velocity, or it generates the ſame velocity in a double, triple, or quadruple quantity of matter, and loſing at the ſame time ſimilar proportions of its own velocity.

Two bodies, having equal quantities of motion, meeting together, mutually ſtop each other.

When two forces, which act ſimilarly during equal times, produce equal velocities in a third body, they will, by acting together during the ſame time, produce a double velocity.

If a preſſure which acts for a ſecond, produce a certain velocity, a double preſſure acting during a ſecond, will produce in the ſame body a double velocity.

A force which is known to act equably, produces in equal times equal increments of velocity, whatever the velocities may be.

In all the examples above adduced, the forces are obſerved to be in the ſame proportion with the change of motion effected by them in a ſimilar way.

Hooke's diſcoveries.

But the curious diſcoveries of Dr Hooke, about the middle of the 17th century, ſeemed to ſhew, from a great collection of facts, forces to be in a very different proportion. In the production of motion it was found, that four ſprings equal in ſtrength, and bent to the ſame degree, generated only a double velocity in the ball which they impelled: nine ſprings generated only a triple velocity, &c. In the extinction of motion, it was found, that a ball moving with a double velocity, will penetrate four times as deep into a uniformly reſiſting maſs; and a triple velocity will make it penetrate nine times as far, &c.

Eſtimation of Leibnitz is incorrect.

130. Theſe facts were brought forward by Leibnitz in ſupport of his own pretenſions to the diſcovery of the real nature and meaſure of mechanical action and force, which he ſaid had been hitherto totally miſtaken. He affirmed, that the inherent force of a moving body was in the proportion of the ſquare of the velocity. In this argument he was ſupported by John Bernoulli, who adduced many ſimple facts to confirm the relation between the inherent force of a moving body and its velocity. One of the ſtrongeſt arguments urged by Leibnitz is, that the inherent force of a moving body is to be eſtimated by all that it is able to do before the total extinction of its motion; and therefore when it penetrates four times as far, it is to be conſidered as having produced a quadruple effect. In this mode of eſtimation many things are gratuitouſly aſſumed, many contradictions are incurred; and it is only becauſe forces are aſſumed as proportional to the velocities which they generate, that theſe facts come to be proportional to the ſquares of the ſame velocities. When Leibnitz aſſumes the quadruple penetration as the proof of the quadruple force of a body having twice the velocity, he has not conſidered that a double time is employed during this penetration. But a double force, acting equably during a double time, ſhould produce a quadruple effect. This circumſtance is loſt ſight of in all the facts which this philoſopher has adduced. It may, however, be obſerved, that Leibnitz, as well as his followers, holds no difference of opinion in all the conſequences which are deduced from the meaſure which is here adopted. They admit, that a force producing an uniformly accelerated motion muſt be conſtant; they agree with the followers of Des Cartes in the valuations both of accelerating and deflecting forces; and have aſſiduouſly and ſucceſsfully cultivated the philoſophy of Newton, which proceeds on the principle of eſtimating the meaſure of moving forces by the velocity generated.

Moving forces only conſidered.

131. It ought here to be obſerved, that *moving forces* only are taken into conſideration. When a ball has acquired a certain velocity, whether it has been impelled by the elaſticity of the air, by a ſpring, or ſtruck off by a blow, or urged forward by means of a ſtream of air or water, or has obtained its velocity by falling; in all theſe caſes it is conceived that it has ſuſtained the ſame action of moving force. The only diſtinct notion, perhaps, which we are able to form, is preſſure; but

Preſſure the moſt diſtinct notion of moving force.

but it is from experience that we derive the information that preſſure produces motion. Whatever may be the difference of the circumſtances of mechanical forces, in one, namely, production of motion, they all agree. In this circumſtance of reſemblance they are capable of compariſon; and from this they derive a name, *moving force*, which is expreſſive of this compariſon. And therefore the particular faculty of preſſure, elaſticity, &c. may be meaſured by the change of motion produced by preſſure. In whatever proportion preſſure may act on a body in a ſtate of reſt, the magnitude of the change of motion meaſures the preſſure actually exerted in its production; and as this is the only change of mechanical condition effected by the preſſure in the body moved by it, it may be meaſured by the velocity. When, therefore, preſſure produces the ſame change of velocity on a ſoft clay ball, the preſſure really exerted is the ſame whether the velocity has been augmented or diminiſhed. In both caſes the ſame dimple will be obſerved. The changes of motion, therefore, are proportional to the exerted preſſures.

Notions of conſtant force the ſame.

132. The notions which we form of a conſtant or invariable force lead to the ſame concluſion. By ſuch a force equal effects or changes of motion are produced in equal times. But equal augmentations of motion are equal augmentations of velocity. This notion of an invariable accelerating force is confirmed by what is obſerved in the caſe of a falling body, which receives equal additions of velocity in equal times; and this force, ſo far as we know, is invariable. The inference then is, that whatever be the force exerted in one ſecond, it will be four times as much in four ſeconds. And this is really the caſe, if it be granted that a quadruple velocity is the indication of a quadruple force; but it does not hold in any other eſtimation of force. Beſides, it may be obſerved, that four ſprings applied to an ounce ball impel it only twice as faſt as one ſpring does; and if the ſame four ſprings be applied to a four ounce ball, they produce in it the ſame velocity that one ſpring produces on an ounce ball. In the laſt caſe, it may be demonſtrated, that the four ſprings act during the ſame time with one ſpring.

Change of motion the meaſure of changing and moving force.

133. The proper meaſure, therefore, of a changing force is a change of motion in all its circumſtances of velocity and direction. This alſo is the proper meaſure of a moving force. For, in different ſtates of motion, bodies may ſuſtain the ſame change of motion. Suppoſing then one of theſe bodies to be previouſly in a ſtate of reſt, the change and the motion acquired are the ſame thing. The force, therefore, producing a change of motion in a moving body, is preciſely the ſame with that force which produces in a body, previouſly at reſt, a motion equivalent to this change; and in this caſe it is ſimply a moving force.

This opinion of Leibnitz about the meaſure of forces has influenced the ſentiments of many writers, and in the mechanical inveſtigations of ſome of them, has not a little affected their practical deductions. No diſpute probably could have occurred if philoſophers had not been led to conſider force as ſomething exiſting in body; the term on the contrary being only uſed to expreſs the phenomenon, which is conceived to be its full effect and adequate meaſure. The ſimple change of motion obſerved is the meaſure of the force by which it is produced.

The following is the enunciation, adapted to the characteriſtic and meaſure of a change of motion.

Law of the Changes of Motion.

Prop. XII.

134. *In every change of motion, the new motion is compounded of the former motion, and of the motion which the changing produces in a body at reſt.*

Let the change of motion be from AB (fig. 23.) to AD, this new motion AD is compounded of the former motion AB and of the motion AC.

For it has been ſhewn, that the change in any motion, is that motion, which when compounded with the former motion, produces the new motion; and the new motion (55.) is the compound of the former motion and the changing motion. Since then the change of motion is the mark and meaſure of the changing force (133.) by which both the direction and intenſity or velocity produced, are determined, the truth of the propoſition will appear of courſe.

133. It has been already obſerved (54.), that the compoſition of motions and the ſimilar compoſition of forces are very different things. The firſt is a pure mathematical truth; the ſecond, is a phyſical queſtion dependent on the nature of the mechanical forces as they exiſt in the univerſe. Our notions are not very diſtinct of two forces, each of which ſeparately produces motions, having the directions and velocities expreſſed by the ſides of a parallelogram, producing by their joint action a motion in the diagonal. The demonſtrations which have been frequently given, are altogether inconcluſive, and only include the compoſition of motions; while gratuitous poſtulates have been aſſumed by thoſe who endeavoured to accommodate their reaſonings to phyſical principles. The celebrated Daniel Bernoulli gave the firſt legitimate demonſtration of this propoſition, in which, however, he employs a ſeries of many propoſitions, ſome of which are very abſtruſe. It was greatly ſimplified by D'Alembert, *Mem. Acad. des Sciences* 1769, ſtill, however, requiring many propoſitions. Ingenious demonſtrations have alſo been given by other celebrated mechanicians. In the following demonſtration by Profeſſor Robiſon, this diſtinguiſhed philoſopher has attempted to combine the demonſtration of Bernoulli, D'Alembert, and others, thus rendering it more expeditious, and at the ſame time legitimate. This demonſtration is entirely limited to preſſures, without at all conſidering or employing the motions ſuppoſed to be produced by them.

(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

tion 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*.

The magnitude *a*—*b*, in like manner, muſt be acknowledged to meaſure that preſſure which ariſes from the joint action of two preſſures *a* and *b* acting in oppoſite directions, of which *a* is the greateſt.

(C) Let ABCD and A*b*C*d* (fig. 24.) be two rhombuſes, which have the common diagonal AC. Let the angles BA*b*, DA*d*, be biſected by the ſtraight lines AE and AF.

If there be drawn from the points E and F the lines EG, EH, F*g*, F*h*, making equal angles on each ſide of EA and FA, and if G*g*, H*h* 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, *g*F*h*, are greater or leſs than GAH, *g*A*h*.

Draw GH, *gh*, cutting AE, AF, in O and *o*, and draw O*o*, 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 G*g*, O*o*, H*h*, 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. 25.), 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 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.

COROLLARY.

(E) 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. 26.) 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*og* 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

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 one-eighth, one-ſixteenth, &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. 27.) 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.

COROLLARY.

(I) 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. 28.) be perpendicular to AC, 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.

COROLLARY.

(L) Thus is the corollary of laſt propoſition extended to every rhombus, whoſe angle at A is ſome multiple of *a* leſs than two right angles. And ſince *a* may be taken leſs than any angle that can be named, the propoſition may be conſidered as demonſtrated of every rhombus; and we may ſay,

(M) Two equal forces, inclined to each other in any angle, compoſe a force which is meaſured by the diagonal of the rhombus, whoſe ſides are the meaſures of the conſtituent forces.

(N) Two forces AB, AC (fig. 29.) 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. 30.) 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.

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.

136. Thus is demonſtrated from abſtract principles the perfect ſimilarity of the compoſition of preſſures and the compoſition of forces meaſured by the motions which are produced. A ſeparate demonſtration ſeems indiſpenſably neceſſary; for what may be deduced from the one caſe is not always applicable to the other. The change produced on a motion already exiſting by a deflecting force, cannot be explained by any compoſition of preſſures; becauſe the changing preſſure is the only one that exiſts, and there is none with which it may be compounded.

compounded. Nor, on the other hand, will our notions of the compoſition of motions explain the compoſition of preſſures, without aſſuming that the preſſures are proportional to the velocities.

137. Conſidering this law of motion merely as a univerſal fact or phyſical law, abundant proof may be adduced in ſupport of it.

1. The joint action of different forces is quite familiar. A lighter, for example, is dragged in different directions by two ropes on different ſides of the canal, the lighter moving in an intermediate direction, as if dragged in that direction by one rope only. A ball moving in a particular direction, which receives a ſtroke acroſs this direction, takes a direction lying between that of the firſt motion and that of the tranſverſe ſtroke.

2. If a particle of matter A (fig. 23.) be urged at once by two preſſures in the directions AB and AC; and if AB and AC be proportional to the intenſities of thoſe preſſures, the joint action of theſe two preſſures is equivalent to the action of a third preſſure in the direction of the diagonal AD, and having its intenſity in the proportion of AD. This is proved by obſerving, that the point A is withheld from moving by a preſſure AE, which is equal and oppoſite to AD. But preſſures are moving forces, producing velocities when they act ſimilarly during equal times, proportional to their intenſities. The proportion, therefore, is true with reſpect to preſſures, conſidered merely as ſuch, and alſo with reſpect to the motions which may be produced by their compoſition.

3. The weight of a ball which is ſuſpended by a thread, and drawn aſide from its poſition in a ſtate of reſt, urges it downwards, and the ball is ſupported obliquely by the thread. Suppoſing this propoſition to be true, the directions and intenſities of the forces inciting it to motion in any poſition, as well as the reſult of the velocities, can be preciſely aſcertained.

4. The motions of the planets computed on theſe principles of the compoſition of forces, do not exhibit any perceptible deviation from calculation, at the end of thouſands of years.

Nothing, therefore, can be relied on with greater confidence than the perfect agreement between the compoſition of motions, and the compoſition of the forces, which, ſeparately taken, would produce thoſe motions, and which are meaſured by the velocities produced. But it ought to be remarked, that if the moving forces are meaſured by the ſquares of the velocities which they generate, the compoſition cannot poſſibly hold; namely, from two forces which are repreſented by the ſides of a parallelogram made proportional to the ſquares of the velocities, there will not reſult a force which can be repreſented by the diagonal. But ſuppoſing the compoſition of forces to be as the velocities, nature exhibits them exactly.—This propoſition, therefore, whether it be conſidered as an abſtract truth or as a phyſical law, may be received as fully eſtabliſhed. The following is the converſe of this propoſition.

Prop. XIII.

138. *The force by which the motion* AB *is changed into* AD, *is that which would produce in a body at reſt, the motion* AC, *and this compounded with* AB *produces the obſerved motion* AD.

Prop. XIV.

139. *The force which will produce in a body at reſt a motion having the direction and velocity repreſented by* AC, *when applied to a body moving with the velocity and in the direction* AB, *will change its motion into the motion* AD, *which is the diagonal of the parallelogram* ABDC. For the new motion muſt be that which is compounded of AB and AC, that is, it muſt be the motion AD.

The combination of theſe two propoſitions gives riſe to the following, which is ſtill more general.

Prop. XV.

140. *A body* A *being urged at once by two forces, which ſeparately would cauſe it to deſcribe* AB *and* AC, *the ſides of a parallelogram* ABDC, *the body by their joint action will deſcribe the diagonal* AD *in the ſame time.*

For if the body had been already moving with the velocity and in the direction AB, and if it had been acted on in A by the force AC, it would deſcribe AD in the ſame time. But it matters not at what time it acquired the determination to deſcribe AB. Let it be then at the inſtant that the force AC is applied to it. And becauſe its mechanical condition in A, which has the determination to the motion AB, is the ſame as in any other point of that line, it muſt deſcribe AD.

Corollary.

Two forces acting on a body in the ſame or in oppoſite directions, will cauſe it to move with a velocity equal to the ſum or to the difference of the velocities which it would have received from the forces ſeparately. For, if AC approach continually to AB by diminiſhing the angle BAC, the points C and D will at laſt fall on *c* and *d*, and then AD is equal to the ſum of AB and AC. But if the angle BAC increaſe continually, the points C and D will at laſt fall on ϰ and ∂, and then A∂ becomes equal to the difference of AB and AC. In the laſt caſe, it is evident, that if AC be equal to AB, the point D or ∂ will coincide with A, and the two forces being equal and acting in oppoſite directions, there will be no motion.

141. In ſuch caſes the equal and oppoſite forces AC and AB are ſaid to *balance* each other; and it is generally ſaid, that theſe forces, by whoſe joint operation no change of motion is produced, balance each other. Such forces are accounted equal and oppoſite, each producing on the body a change of motion equal to what it would produce on a body at reſt, and at the ſame time equal to the motion produced by the other force on a body at reſt. The two motions being equal and oppoſite, the forces are therefore equal and oppoſite.

142. What has been demonſtrated concerning the affections with reſpect to the affections of compound motions, may now be applied to the combination of forces; taking care, however, to recollect the eſſential difference between the compoſition of motions and the compoſition of forces. In the combination of forces, the compoſition is complete, when the determination has been given to the body to move with the proper velocity in the diagonal. When the body has acquired this determination, there is no farther compoſition; and it continues its uniform motion, till its condition be changed.

changed by ſome new force. On the other hand, in the compoſition of two or more motions, the conſtituent motions are ſuppoſed to continue; and it is only during their continuance that the compound motion exiſts. If it be poſſible, which does not appear to be the caſe, that any force can generate a finite velocity by its inſtantaneous action, two ſuch forces generate in an inſtant the determination in the diagonal. But ſuppoſing the action to continue for ſome time, to generate the velocities AB or AC, there muſt be a continuance of the joint action during the ſame time to produce the velocity AD. And although the moving powers of the two forces may vary in their intenſity, yet it is neceſſary that they retain the ſame proportion to each other during the whole time of their joint action. Overlooking this circumſtance, experiments have been made for the purpoſe of comparing this doctrine with the phenomena; and they have been found to exhibit very different reſults. But experiments made by the combination of preſſures, ſuch as weights pulling a body by means of threads, coincide preciſely with this doctrine; for it is always found that two weights pulling in the directions AB, AC, and proportional to thoſe lines, are balanced by a third weight in the proportion of AD, and pulling in the direction AE. In this way the compoſition of preſſures is clearly proved; and, having no other diſtinct conception of a moving force, theſe experiments may be conſidered as ſufficient. But we may go farther; for there is the cleareſt proof by experiment, that preſſures produce motions in proportion to their intenſities by their ſimilar action during equal times. In the planetary motions, the directions and intenſities of the compound forces are accurately known as moving forces. Theſe motions afford a complete proof of the phyſical law, by their perfect coincidence with the calculations which proceed on the principles of this doctrine. This coincidence muſt be acknowledged as a full proof of the propriety of the meaſure which has been aſſumed. The aſſumption of any other meaſure would exhibit reſults quite different from the phenomena.

143. Forces which produce motions along the ſides of a parallelogram are called *ſimple forces* or *conſtituent forces*. And the force which ſingly produces the motion in the diagonal, is called the *equivalent force*, the *compound force*, or the *reſulting force*.

144. Some general concluſions may now be pointed out, which will facilitate greatly the uſe of the parallelogram of forces.

General Corollaries.

1. The conſtituent and the reſulting forces, or the ſimple and compound forces, act in the ſame plane; for the ſides and diagonal of a parallelogram are in one plane.

2. The ſimple and the compound forces are 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. 31.), 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.

3. Therefore each is proportional to the ſine of the oppoſite angle of this triangle; for the ſides of any triangle are proportional to the ſines of the oppoſite angles.

4. Each is proportional to the ſine of the angle contained by the directions of the other two; for AD is to AB as the ſine of the angle ABD to the ſine of the angle ADB. Now the ſine of ABD is the ſame with 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.

Special uſes of the parallelogram of forces.

145. Let us 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.

Equivalent of many forces.

146. This theorem is not limited to the compoſition of two forces only; for ſince the combined action of two forces puts the body into the ſame ſtate as if their equivalent alone had acted on it, we may ſuppoſe this to have been the caſe, and then the action of a third force will produce a change on this equivalent motion. The reſulting motion will be the ſame as if only this third force and the equivalent of the other two had acted on the body. Thus, in fig. 32. 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.

147. 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 and very uſeful theorem.

Three forces having the proportion and direction of the three ſides of a parallelopided, compoſe a force having the proportion and direction of the diagonal.

148. In the inveſtigation of very complicated phenomena, the mechanician conſiders every force as reſulting from the joint action of three forces at right angles to each other, and he takes the ſum or difference of theſe in the ſame or oppoſite directions. Thus he obtains the three ſides of a parallelopiped, and from theſe computes the poſition and magnitude of the diagonal. This is the force reſulting from the compoſition of all the partial ones. This proceſs is called the *eſtimation* or *reduction of forces*. Forces may be eſtimated in the direction of a given line or plane, or they may be reduced to that direction, as has been done with reſpect to motion. See Cor. 2. Propoſ. 9. in Art. 57.

The laws of motion which have now been conſidered, are neceſſary conſequences of the relations of thoſe conceptions which we form of motion and mechanical force, and they are univerſal facts or phyſical laws. To theſe Sir Iſaac Newton has added another, which is the following.

Third Law of Motion.

149. *Every action is accompanied by an equal and contrary reaction*, or *the actions of bodies on one another are always mutual, equal, and in contrary directions.*

In all caſes which can be accurately examined, this holds to be a univerſal fact. Newton has made this affirmation on the authority of what he conceives to be a law of human thought; namely that the qualities diſcovered in all bodies on which experiments and obſervations can be made, are to be conſidered as univerſal qualities of body. But if the term law of motion be limited to thoſe conſequences that neceſſarily flow from our notions of motion, of the cauſes of its production and changes, this propoſition is not ſuch a reſult. Becauſe a magnet cauſes the iron to approach toward it, it by no means follows from this obſervation that the preſſure of the iron ſhall be accompanied by any motion or change of ſtate of the magnet, or it does not appear to be neceſſarily ſuppoſed that the iron attracts the magnet. When this was obſerved, it was accounted a diſcovery, and a diſcovery which is to be aſcribed to the moderns. Dr Gilbert, who firſt mentions it, affirms that the magnet and the iron are obſerved mutually to attract each other, as well as all electrical ſubſtances, and the light bodies which are attracted by them. The diſcovery was made by Kepler that a mutual attraction exiſts between the earth and the moon. Newton diſcovered that the ſun acts on the planets, and that the earth acts on the moon. It had been obſerved too by Newton that the iron reacts on the magnet, that the actions of electrified bodies are mutual, and that all the actions of ſolid bodies are accompanied by an equal and contrary reaction. On the authority of the rule of philoſophizing which he had laid down, he affirmed that the planets react on the ſun, and that the ſun is not at reſt, but is continually agitated by a ſmall motion round the general centre of gravitation; and he pointed out ſeveral of the conſequences of this reaction. As the celeſtial motions were more narrowly examined by aſtronomers, theſe conſequences were found to obtain, and to produce diſturbances in the planetary motions. This reciprocity of action is now found to hold with the utmoſt preciſion through the whole of the ſolar ſyſtem; and therefore this third propoſition of Newton is to be conſidered as a law of nature. And it is true with reſpect to all bodies on which experiment or obſervation can be made.

150. This then being a univerſal law, we cannot diveſt our minds of the belief that it depends on a general principle, by which all the matter in the univerſe is influenced. It ſtrongly induces the perſuaſion of the ultimate particles of matter being alike, that a certain number of properties belong in the ſame degree to each atom, and that all the ſenſible differences of ſubſtance which are obſerved, ariſe from a different combination of thoſe primary atoms in the formation of a particle of thoſe ſubſtances. All this is no doubt perfectly poſſible. But if each primary atom be ſo conſtituted, no action of any kind of particle or collection of particles can take place on another, which is not accompanied by an equal reaction in the oppoſite direction.

151. Let us now direct our attention to the application of theſe laws. This anſwers a twofold purpoſe. The firſt is to diſcover the mechanical powers of natural ſubſtances by which they are fitted to become parts of a permanent univerſe. This is accompliſhed by obſerving the changes of motion which always accompany thoſe ſubſtances. It is from theſe changes that the only characteriſtics of powers are derived; and thus is diſcovered the power of gravity, of magnetiſm, &c. Another purpoſe in the employment of theſe laws is, that, after having obtained the mechanical character of any ſubſtance, we may aſcertain what will be the reſult of its being in the vicinity of the bodies mechanically allied, or we may aſcertain what is the change induced on the condition of the neighbouring bodies.

152. The mechanical powers of bodies occaſionally produce accelerations, retardations, and deflections in the motions of other bodies. Theſe names have been given, becauſe nothing is known of their nature, or of the manner in which they are effective; they are therefore named, as they are meaſured by the phenomena which are obſerved and conſidered as their effects. Let us now attend a little to the principal circumſtances relating to the action of theſe forces.

Of Accelerating and Retarding Forces.

153. Changes of motion are the only marks and meaſures of changing forces; and having no other mark of the force but the acceleration, it has obtained the name of an *accelerating force*. When the motion is retarded it is called *retarding force*. Nor is there any other meaſure of the intenſity of an accelerating force, but the acceleration which it produces. To inveſtigate therefore the powers which produce all the changes of motion it is neceſſary to obtain meaſures of the acceleration. What has been ſaid of accelerations and retardations of motion is equally deſcriptive of the effects of accelerating and retarding forces. Hence the following propoſition.

If the abſciſſa a d fig. 5. *repreſent the time of any motion, and if the areas* a b f e, a c g e &c. *are as the velocities at the inſtants* b c, &c. *the ordinates* a e, b f, c g, &c. *are as the accelerating forces at thoſe inſtants.*

COROLLARIES.

Cor. 1. The momentary change of velocity is as the force f and the time t jointly. It may be thus expreſſed.

$$\dot{v}, \text{ or } -\dot{v} \doteqdot f\dot{t}.$$

Alſo, the accelerating or retarding force is proportional to the momentary variation of the velocity, directly, and to the moment of time in which it is generated, inverſely (48).

$$f \doteqdot \frac{\dot{v}}{\dot{t}}, \text{ or } \doteqdot \frac{-\dot{v}}{\dot{t}}.$$

Indeed, all that we know of force is that it is ſomething which is always proportional to $\frac{\dot{v}}{\dot{t}}$.

Cor. 2. *Uniformly accelerated or retarded motion is the indication of a conſtant or invariable accelerating force.* For, in this caſe, the areas $a\,b\,f\,e$, $a\,c\,g\,e$, &c. increaſe at the ſame rate with the times $a\,b$, $a\,c$, &c. and therefore the ordinates $a\,e$, $b\,f$, $c\,g$, &c. muſt all be equal; therefore the forces repreſented by them are the ſame, or the accelerating force does not change its intenſity, or, it is conſtant. If, therefore, the circumſtances mentioned in articles 37 and 38, are obſerved in any motion, the force is conſtant. And if the force is known to be conſtant, thoſe propoſitions are true reſpecting the motions.

Cor. 3. *No finite change of velocity is generated in an inſtant by an accelerating or retarding force.* For the increment or decrement of velocity is always expreſſed by an area, or by a product $f\dot{t}$, one ſide or factor of which is a portion of time. As no finite ſpace can be deſcribed in an inſtant, and the moveable muſt paſs in ſucceſſion through every point of the path, ſo it muſt acquire all the intermediate degrees of velocity. It muſt be *continually* accelerated or retarded.

Cor. 4. The change of velocity produced in a body in any time, by a force varying in any manner, is the proper meaſure of the accumulated or whole action of the force during this time. For, ſince the momentary change of velocity is expreſſed by $f\dot{t}$, the aggregate of all theſe momentary changes, that is, the whole change of velocity, muſt be expreſſed by the ſum of all the quantities $f\dot{t}$. This is equivalent to the area of the figure employed in art. 148, and may be expreſſed by $\int f\dot{t}$.

154. *If the abſciſſa* AE (fig. 8.) *of the line* a c e *be the path along which a body is urged by the action of a force, varying in any manner, and if the ordinates* A a, B b, C c, &c. *be proportional to the intenſities of the force in the different points of the path, the intercepted areas will be proportional to the changes made on the ſquare of the velocity during the motion along the correſponding portions of the path.*

For, by art. 49, the areas are in this proportion when the ordinates are as the accelerations. But the accelerations are the meaſures of, and are therefore proportional to, the accelerating forces. Therefore the propoſition is manifeſt.

COROLLARY.

The momentary change on the ſquare of the velocity is as the force, and as the ſmall portion of ſpace along which it acts, jointly;

$$v\dot{v} \doteqdot f\dot{s}$$

and $$f \doteqdot \frac{v\dot{v}}{\dot{s}}.$$

155. It deſerves remark here, that as the momentary change of the ſimple velocity by any force f depends only on the time of its action, it being $= f\dot{t}$ (148.) Cor. 1. ſo the change on the ſquare of the velocity depends on the ſpace, it being $= f\dot{s}$. It is the ſame, whatever is the velocity thus changed, or even though the body be at reſt when the force begins to act on it. Thus, in every ſecond of the falling of a heavy body, the velocity is augmented 32 feet per ſecond, and in every foot of the fall, the ſquare of the velocity increaſes by 64.

156. The whole area AE $e\,a$, expreſſed by $\int f\dot{s}$, expreſſes the whole change made on the ſquare of the velocity which the body had in A, whatever this velocity may have been. We may therefore ſuppoſe the body to have been at reſt in A. The area then meaſures the ſquare of the velocity which the body has acquired in the point E of its path. It is plain that the change on v^2 is quite independent on the time of action, and therefore a body, in paſſing through the ſpace AE with any initial velocity whatever, ſuſtains the ſame change of the ſquare of that velocity, if under the influence of the ſame force.

157. This propoſition is the ſame with the 39th of the Firſt Book of Newton's Principia, and is perhaps the moſt generally uſeful, of all the theorems in Dynamics, in the ſolution of practical queſtions. It is to be found, without demonſtration, in his earlieſt writings, the Optical Lectures, which he delivered in 1669 and following years.

158. One important uſe may be made of it at preſent. It gives a complete ſolution of all the facts which were obſerved by Dr Hooke, and adduced by Leibnitz with ſuch pertinacity in ſupport of his meaſure of the force of moving bodies. All of them are of preciſely the ſame nature with the one mentioned in art. 157, or with the fact, "that a ball projected directly upwards "with a double velocity, will riſe to a quadruple height, "and that a body, moving twice as faſt, will penetrate "four times as far into a uniformly tenacious maſs." The uniform force of gravity, or the uniform tenacity of the penetrated body, makes a uniform oppoſition to the motion, and may therefore be conſidered as a uniform retarding force. It will therefore be repreſented, in fig. 8, by an ordinate always of the ſame length, and the areas which meaſure the ſquare of the velocity loſt will be portions of a rectangle AE $\epsilon\,a$. If therefore AE be the penetration neceſſary for extinguiſhing the velocity 2, the ſpace AB, neceſſary for extinguiſhing the velocity 1, muſt be $\frac{1}{4}$ of AE, becauſe the ſquare of 1 is $\frac{1}{4}$ of the ſquare of 2.

159. What particularly deſerves remark here, is, that this propoſition is true, *only on the ſuppoſition that forces are proportional to the velocities generated by them in equal times.* For the demonſtration of this propoſition proceeds entirely on the previouſly eſtabliſhed meaſure of

of acceleration. We had $\dot{v} \doteqdot f\dot{t}$; therefore $v\dot{v} \doteqdot f\dot{t}v$. But $\dot{t}v \doteqdot \dot{s}$; therefore $v\dot{v} \doteqdot f\dot{s}$, which is preciſely this propoſition.

160. Thoſe may be called *ſimilar* points of ſpace, and *ſimilar* inſtants of time, which divide given portions of ſpace or time in the ſame ratio. Thus, the beginning of the 5th inch, and of the 2d foot, are ſimilar points of a foot, and of a yard. The beginning of the 21ſt minute, and of the 9th hour, are ſimilar inſtants of an hour, and of a day.

Forces may be ſaid to act *ſimilarly* when, in ſimilar inſtants of time, or ſimilar points of the path, their intenſities are in a conſtant ratio.

161. *Lemma.* If two bodies be ſimilarly accelerated during given times $a\,c$ and $h\,k$ (fig. 33.), they are alſo ſimilarly accelerated along their reſpective paths AC and HK.

Let a, b, c be inſtants of the time $a\,c$, ſimilar to the inſtants h, i, k of the time $h\,k$. Then, by the ſimilar accelerations, we have the force $a\,e : h\,l = b\,f : i\,m$. This being the caſe throughout, the area $a\,f$ is to the area $h\,m$ as the area $a\,g$ to the area $h\,n$. Theſe areas are as the velocities in the two motions 48. Therefore the velocities in ſimilar inſtants are in a conſtant ratio, that is, the velocity in the inſtant b is to that in the inſtant i, as the velocity in the inſtant c to that in the inſtant k.

The figures may now be taken to repreſent the times of the motion by their abſciſſæ, and the velocities by their ordinates, as in art. 28. The ſpaces deſcribed are now repreſented by the areas. Theſe being in a conſtant ratio, as already ſhewn, we have A, B, C, and H, I, K, ſimilar points of the paths. And therefore, in ſimilar inſtants of time, the bodies are in ſimilar points of the paths. But in theſe inſtants, they are ſimilarly accelerated, that is, the accelerations and the forces are in a conſtant ratio. They are therefore in a conſtant ratio in ſimilar points of the paths, and the bodies are ſimilarly accelerated along their reſpective paths (155.)

162. *If two particles of matter are ſimilarly urged by accelerating or retarding forces during given times, the whole changes of velocity are as the forces and times jointly; or* $v \doteqdot f\,t$.

For the abſciſſæ $a\,c$ and $h\,k$ will repreſent the times, and the ordinates $a\,e$ and $h\,l$ will repreſent the forces, and then the areas will repreſent the changes of velocity, by art. 47. And theſe areas are as $a\,c \times a\,e$ to $h\,k \times h\,l$.

Hence $t \doteqdot \frac{v}{f}$, and $f \doteqdot \frac{v}{t}$.

163. *If two particles of matter are ſimilarly impelled or oppoſed through given ſpaces, the changes in the ſquares of velocity are as the forces and ſpaces jointly; or* $\doteqdot f\,s$.

This follows, by ſimilar reaſoning, from art. 49.

It is evident that this propoſition applies directly to the argument ſo confidently urged for the propriety of the Leibnitzian meaſure of forces, namely, that four ſprings of equal ſtrength, and bent to the ſame degree, generate, or extinguiſh only a double velocity.

164. *If two particles of matter are ſimilarly impelled through given ſpaces, the ſpaces are as the forces and the ſquares of the times jointly.*

For the moveables are ſimilarly urged during the times of their motion (converſe of 156.) Therefore $v \doteqdot f\,t$, and $v^2 \doteqdot f^2\,t^2$; but (158.) $v^2 \doteqdot f\,s$. Therefore $f\,s \doteqdot f^2\,t^2$ and $s \doteqdot f\,t^2$.

Corollary.

$t^2 \doteqdot \frac{s}{f}$, and $f \doteqdot \frac{s}{t^2}$. That is, the ſquares of the times are as the ſpaces, directly, and as the forces, inverſely; and the forces are as the ſpaces, directly, and as the ſquares of the times, inverſely.

165. The quantity of motion in a body is the ſum of the motions of all its particles. Therefore, if all are moving in one direction, and with one velocity v, and if m be the number of particles, or quantity of matter, $m\,v$ will expreſs the quantity of motion q, or $q \doteqdot m\,v$.

166. In like manner, we may conceive the accelerating forces f, which have produced this velocity v in each particle, as added into one ſum, or as combined on one particle. They will thus compoſe a force, which, for diſtinction's ſake, it is convenient to mark by a particular name. We ſhall call it the MOTIVE FORCE, and expreſs it by the ſymbol p. It will then be conſidered as the aggregate of the number m of equal accelerating forces f, each of which produces the velocity v on one particle. It will produce the velocity $m\,v$, and the ſame quantity of motion q.

167. Let there be another body, conſiſting of n particles, moving with one velocity u. Let the moving force be repreſented by π. It is meaſured in like manner by $n\,u$. Therefore we have, $p : \pi = m\,v : n\,u$, and $v : u = \frac{p}{m} : \frac{\pi}{n}$; that is,

The velocities which may be produced by the ſimilar action of different motive forces, in the ſame time, are directly as theſe forces, and inverſely as the quantities of matter to which they are applied.

In general, $\dot{v} \doteqdot \frac{p}{m}$,

And f being $= \frac{\dot{v}}{\dot{t}}$, $f \doteqdot \frac{p}{m\dot{t}}$.

Remark.

168. In the application of the theorems concerning accelerating or retarding forces, it is neceſſary to attend carefully to the diſtinction between an accelerative and a motive force. The caution neceſſary here has been generally overlooked by the writers of Elements, and this has given occaſion to very inadequate and erroneous notions of the action of accelerating powers. Thus, if a leaden ball hangs by a thread, which paſſes over a pulley, and is attached to an equal ball, moveable along a horizontal plane, without the ſmalleſt obſtruction, it is known, that, in one ſecond, it will deſcend 8 feet, dragging the other 8 feet along the plane, with a uniformly accelerated motion, and will generate in it the velocity 16 feet per ſecond. Let the thread be attached to three ſuch balls. We know that it will deſcend 4 feet in a ſecond, and generate the velocity 8 feet per ſecond. Moſt readers are diſpoſed to think that it ſhould generate no greater velocity than $5\frac{1}{3}$ feet per ſecond, or $\frac{1}{3}$ of 16, becauſe it is applied to three times as much matter (162.) The error

error lies in conſidering the motive force as the ſame in both caſes, and in not attending to the quantity of matter to which it is applied. Neither of theſe conjectures is right. The motive force changes as the motion accelerates, and in the firſt caſe, it moves two balls, and in the ſecond it moves four. The motive force decreaſes ſimilarly in both motions. When theſe things are conſidered, we learn by articles 202 and 207, that the motions will be preciſely what we obſerve.

Of Deflecting Forces, in General.

169. It was obſerved, in art. 71, that a curvilineal motion is a caſe of *continual* deflection. Therefore, when ſuch motions are obſerved, we know that the body is under the *continual* influence of ſome natural force, acting in a direction which croſſes that of the motion in every point. We muſt infer the magnitude and direction of this deflecting force by the magnitude and direction of the obſerved deflection. Therefore, all that is affirmed concerning deflections in the 71ſt and ſubſequent articles, may be affirmed concerning deflecting forces. It follows, from what has been eſtabliſhed concerning the action of accelerating forces, that no force can produce a finite change of velocity in an inſtant. Now, a deflection is a compoſition of a motion already exiſting with a motion accelerated from reſt by inſenſible degrees. Suppoſing the deflecting force of invariable direction and intenſity, the deflection is the compoſition of a motion having a finite velocity with a motion uniformly accelerated from reſt. Therefore the linear deflection from the rectilineal motion muſt increaſe by inſenſible degrees. The curvilineal path, therefore, muſt have the line of undeflected motion for its tangent. To ſuppoſe any finite angle contained between them would be to ſuppoſe a polygonal motion, and a ſubſultory deflection.

Therefore *no finite change of direction can be produced by a deflecting force in an inſtant.*

170. The moſt general and uſeful propoſition on this ſubject is the following, founded on art. 75.

The forces by which bodies are deflected from the tangents in the different points of their curvilineal paths are proportional to the ſquares of the velocities in thoſe points, directly, and inverſely to the deflective chords of the equicurve circles in the ſame points. We may ſtill expreſs the propoſition by the ſame ſymbol

$$f \div \frac{v^2}{c},$$

where *f* means the intenſity of the deflecting force.

171. We may alſo retain the meaning of the propoſition expreſſed in article 76, where it is ſhewn that the actual linear deflection from the tangent is the third proportional to the deflective chord and the arch deſcribed in a very ſmall moment. For it was demonſtrated in that article (ſee fig. 18.) that BZ : BC = BC : BO.

We ſee alſo that B *b*, the double of BO, is the meaſure of the velocity, generated by the uniform action of the deflecting force, during the motion in the arch BC of the curve.

172. The art. 77. alſo furniſhes a propoſition of frequent and important uſe, viz.

The velocity in any point of a curvilinear motion is that which the deflecting force in that point would generate in the body by uniformly impelling it along the fourth part of the deflective chord of the equicurve circle.

Remark.

173. The propoſitions now given proceed on the ſuppoſition that, when the points A and C of fig. 18, after continually approaching to B, at laſt coaleſce with it, the laſt circle which is deſcribed through theſe three points has the ſame curvature which the path has in B. It is proper to render this mode of ſolving theſe queſtions more plain and palpable.

If ABCD (fig. 35.) be a material curve or mould, and a thread be made faſt to it at D, this thread may be lapped on the convexity of this curve, till its extremity meets it in A. Let the thread be now unlapped or EVOLVED from the curve, keeping it always tight. It is plain that its extremity A will deſcribe another curve line A *b c*. All curves, in which the curvature is neither infinitely great nor infinitely ſmall, may be thus deſcribed by a thread evolved from a proper curve. The properties of the curve A *b c* being known, Mr Huyghens (the author of this way of generating curve lines) has ſhewn how to conſtruct the evolved curve ABC which will produce it.

From this geneſis of curves we may infer, 1ſt, that the detached portion of the thread is always a tangent to the curve ABC; 2dly, that when this is in any ſituation B *b*, it is perpendicular to the tangent of the curve A *b c* in the point *b*, and that it is, at the ſame time, deſcribing an element of that curve, and an element of a circle α *b* κ, whoſe momentary centre is B, and which has B *b* for its radius. 3dly, That the part *b* A of the curve, being deſcribed with radii growing continually ſhorter, is *more* incurvated than the circle *b* α, which has B *b* for its conſtant radius. For ſimilar reaſons the arch *b c* of the curve A *b c* is *leſs* incurvated than the circle α *b* κ. 4thly, That the circle α *b* κ has the ſame curvature that the curve has in *b*, or is an equicurve circle. B *b* is the radius, and B the centre of curvature in the point *b*.

ABC is the CURVA EVOLUTA or the EVOLUTE. A *b c* is ſometimes called the INVOLUTE of ABC, and ſometimes its EVOLUTRIX.

174. By this way of deſcribing curve lines, we ſee clearly that a body, when paſſing through the point *b* of the curve A *b c* may be conſidered as in the ſame ſtate, in that inſtant, as in paſſing through the ſame point *b* of the circle α *b* κ; and the ultimate ratio of the deflections in both is that of equality, and they may be uſed indiſcriminately.

The chief difficulty in the application of the preceding theorems to the curvilineal motions which are obſerved in the ſpontaneous phenomena of nature, is in aſcertaining the direction of the deflection in every point of a curvilineal motion. Fortunately, however, the moſt important caſes, namely thoſe motions, where the deflecting forces are always directed to a fixed point, afford a very accurate method. Such forces are called by the general name of

Central Forces.

175. *If bodies deſcribe circles with a uniform motion, the deflecting forces are always directed to the centres of the*

the circles, and are proportional to the ſquare of the velocities, directly, and to their diſtances from the centre, inverſely.

For, ſince their motion in the circumference is uniform, the areas formed by lines draw from the centre are as the times, and therefore (72.) the deflections, and the deflecting forces (164.) are directed to the centre. Therefore, the deflective chord is, in this caſe, the diameter of the circle, or twice the diſtance of the body from the centre. Therefore, if we call the diſtance from the centre d, we have $f \doteqdot \frac{v^2}{d}$.

176. *Theſe forces are alſo as the diſtances, directly, and as the ſquare of the time of a revolution, inverſely.*

For the time of a revolution (which may be called the PERIODIC TIME) is as the circumference, and therefore as the diſtance, directly, and as the velocity, inverſely. Therefore $t \doteqdot \frac{d}{v}$, and $v \doteqdot \frac{d}{t}$, and $v^2 \doteqdot \frac{d^2}{t^2}$, and $\frac{v^2}{d} \doteqdot \frac{d}{t^2}$.

177. *Theſe forces are alſo as the diſtances, and the ſquare of the angular velocity, jointly.*

For, in every uniform circular motion, the angular velocity is inverſely as the periodic time. Therefore, calling the angular velocity a, $a^2 \doteqdot \frac{1}{t^2}$, and $\frac{d}{t^2} \doteqdot d\,a^2$, and therefore $f \doteqdot d\,a^2$.

178. *The periodic time is to the time of falling along half the radius by the uniform action of the centripetal force in the circumference, as the circumference of a circle is to the radius.*

For, in the time of falling through half the radius, the body would deſcribe an arch equal to the radius (37.—6.) becauſe the velocity acquired by this fall is equal to the velocity in the circumference (167.) The periodic time is to the time of deſcribing that arch as the circumference to the arch, that is, as the circumference is to the radius.

179. *When a body deſcribes a curve which is all in one plane, and a point is ſo ſituated in that plane, that a line drawn from it to the body deſcribes round that point areas proportional to the times, the deflecting force is always directed to that point* (72.)

180. Converſely. *If a body is deflected by a force always directed to a fixed point, it will deſcribe a curve line lying in one plane which paſſes through that point, and the line joining it with the centre of forces will deſcribe areas proportional to the times* (73.)

The line joining the body with the centre is called the RADIUS VECTOR. The deflecting force is called CENTRIPETAL, or ATTRACTIVE, if its direction be always *toward* that centre. It is called REPULSIVE, or CENTRIFUGAL, if it be directed outwards *from* the centre. In the firſt caſe, the curve will have its *concavity* toward the centre, but, in the ſecond caſe, it will be *convex* toward the centre. The force which urges a piece of iron towards a magnet is centripetal, and that which cauſes two electrical bodies to ſeparate is centrifugal.

181. *The force by which a body may be made to deſcribe circles round the centre of forces, with the angular velocities which it has in the different points of its curvilineal path, are inverſely as the cubes of its diſtances from the centre of forces.* For the centripetal force in circular motions is proportional to $d\,a^2$ (172.) But when the deflections (and conſequently the forces) are directed to a centre, we have $a \doteqdot \frac{1}{d^2}$ (75.) and $a^2 \doteqdot \frac{1}{d^4}$, therefore $d\,a^2 \doteqdot d \times \frac{1}{d^4}, \doteqdot \frac{1}{d^3}$, therefore $f \doteqdot \frac{1}{d^3}$.

This force is often called centrifugal, *the centrifugal force of circular motion*, and it is conceived as always acting in every caſe of curvilineal motion, and to act in oppoſition to the centripetal force which produces that motion. But this is inaccurate. We ſuppoſe this force, merely becauſe we muſt employ a centripetal force, juſt as we ſuppoſe a *reſiſting* vis inertiæ, becauſe we muſt employ force to move a body.

182. *If a body deſcribe a curve line* ABC *by means of a centripetal* (fig. 36.) *force directed to* S, *and varying according to ſome proportion of the diſtances from it, and if another body be impelled toward* S *in the ſtraight line* a b S *by the ſame force, and if the two bodies have the ſame velocity in any points* A *and* a *which are equidiſtant from* S, *they will have equal velocities in any other two points* C *and* c, *which are alſo equidiſtant from* S.

Deſcribe round S, with the diſtance SA, the circular arch A *a*, which will paſs through the equidiſtant point *a*. Deſcribe another arch B *b*, cutting off a ſmall arc AB of the curve, and alſo cutting AS in D. Draw DE perpendicular to the curve.

The diſtances AS and *a* S being equal, the centripetal forces are alſo equal, and may be repreſented by the equal lines AD and *a b*. The velocities at A and *a* being equal, the times of deſcribing AB and *a b* will be as the ſpaces (14.) The force *a b* is wholly employed in accelerating the rectilineal motion along *a* S. But the force AD, being tranſverſe or oblique to the motion along AB, is not wholly employed in thus accelerating the motion. It is equivalent to the two forces AE and ED, of which ED, being perpendicular to AB, neither promotes nor oppoſes it, but incurvates the motion. The accelerating force in A therefore is AE. It was ſhewn, in art. 48, that the change of velocity is as the force and as the time jointly, and therefore it is as $AE \times AB$. For the ſame reaſon, the change of the velocity at *a* is as $a\,b \times a\,b$, or $a\,b^2$. But, as the angle ADB is a right angle, as alſo AED, we have $AE : AD = AD : AB$, and $AE \times AB = AD^2, = a\,b^2$. Therefore, the increments of velocity acquired along AB and *a b* are equal. But the velocities at A and *a* were equal. Therefore the velocities at B and *b* are alſo equal. The ſame thing may be ſaid of every ſubſequent increaſe of velocity, while moving along BC and *b c*; and therefore the velocities at C and *c* are equal.

The ſame thing holds, when the deflecting force is directed in lines parallel to *a* S, as if to a point S′ infinitely diſtant, the one body deſcribing the curve line VA′B′, while the other deſcribes the ſtraight line VS.

183. The propoſitions in art 73. and 74. are alſo true in curvilineal motions by means of central forces.

When the path of the motion is a line returning into itſelf, like a circle or oval, it is called an ORBIT; otherwiſe it is called a TRAJECTORY.

The time of a complete revolution round an orbit is called the PERIODIC TIME.

184. The formula $f \doteqdot \frac{v^2}{c}$ ſerves for diſcovering the law of variation of the central force by which a body deſcribes the different portions of its curvilineal path; and the formula $f \doteqdot \frac{d}{t^2}$ ſerves for comparing the forces by which different bodies deſcribe their reſpective orbits.

185. It muſt always be remembered, in conformity to art. 77. that $f = \frac{v^2}{c}$ or $f = \frac{\text{arc}^2}{c}$ expreſſes the linear deflection from the tangent, which may be taken for a meaſure of the deflecting force, and that $f = \frac{2\,v^2}{c}$ or $f = \frac{2\,\text{arc}^2}{c}$ expreſſes the velocity generated by this force, during the deſcription of the arc, or the velocity which may be compared directly with the velocity of the motion in the arc. The laſt is the moſt accurate, becauſe the velocity generated is the real change of condition.

186. *A body may deſcribe, by the action of a centripetal force, the direction of which paſſes through* C (fig. 36.), *a figure* VPS, *which figure revolves (in its own plane) round the centre of forces* C, *in the ſame manner as it deſcribes the quieſcent figure, provided that the angular motion of the body in the orbit be to that of the orbit itſelf in any conſtant ratio, ſuch as that of* m *to* n.

For, if the direction of the orbit's motion be the ſame with that of the body moving in it, the angular motion of the body in every point of its motion is increaſed in the ratio of m to $n+m$, and it will be in the ſame ratio in the different parts of the orbit as before, that is, it will be inverſely as the ſquare of the diſtance from S (75). Moreover, as the diſtances from the centre in the ſimultaneous poſitions of the body, in the quieſcent and in the revolving orbit, are the ſame, the momentary increments of the area are as the momentary increments of the angle at the centre; and therefore, in both motions, the areas increaſe in the conſtant ratio of m to $m+n$ (75.) Therefore the areas of the abſolute path, produced by the compoſition of the two motions, will ſtill be proportional to the times; and therefore (73.) the deflecting force muſt be directed to the centre S; or, a force ſo directed will produce this compound motion.

187. *The differences between the forces by which a body may be made to move in the quieſcent and in the moveable orbit are in the inverſe triplicate ratio of the diſtances from the centre of forces.*

Let VKSBV (fig. 36.) be the fixed orbit, and $u\,p\,k\,b\,u$ the ſame orbit moved into another poſition; and let $V\,p\,n\,N\,o\,N\,t\,QV$ be the orbit deſcribed by the body in abſolute ſpace by the compoſition of its motion in the orbit with the motion of the orbit itſelf. If the body be ſuppoſed to deſcribe the arch VP of the fixed orbit while the axis VC moves into the ſituation uC, and if the arch $u\,p$ be made equal to VP, then p will be the place of the body in the moveable orbit, and in the compound path Vp. If the angular motion in the fixed orbit be to the motion of the moving orbit as m to n, it is plain that the angle VCP is to VCp as m to $m+n$. Let PK and $p\,k$ be two equal and very ſmall arches of the fixed and moving orbits. PC and $p\,c$ are equal, as are alſo KC and k C, and a circle deſcribed round C with the radius CK will paſs through k. If we now make VCK to VCn as m to $m+n$: the point n of the circle K$\,k\,n$ will be the point of the compound path, at which the body in the moving orbit arrives when the body in the fixed orbit arrives at K, and $p\,n$ is the arch of the abſolute path deſcribed while PK is deſcribed in the fixed path.

In order to judge of the difference between the force which produces the motion PK in the fixed orbit and that which produces $p\,n$ in the abſolute path, it muſt be obſerved that, in both caſes, the body is made to approach the centre by the difference between CP and CK. This happens, becauſe the centripetal forces, in both caſes, are greater than what would enable the body to deſcribe circles round C, at the diſtance CP, and with the ſame angular velocities that obtain in the two paths, viz. the fixed orbit and the abſolute path. We ſhall call the one pair of forces the *circular forces*, and the other the *orbital*. Let C and c repreſent the forces which would produce circles, with the angular velocities which obtain in the fixed and moving orbits, and let O and o be the forces which produce the orbital motions in theſe two paths.

Theſe things being premiſed, it is plain that $o-c$ is equal to O—C, becauſe the bodies are equally brought towards the centre by the difference between O and C and by that between o and c. Therefore $o-\mathrm{O}$ is equal to $c-\mathrm{C}$ (A). The difference, therefore, of the forces which produce the motions in the fixed and moving orbits is always equal to the difference of the forces which would produce a circular motion at the ſame diſtances, and with the ſame angular velocity. But the forces which produce circular motions, with the angular motion that obtains in an orbit at different diſtances from the centre of forces, are as the cubes of the diſtances inverſely (175.) And the two angular motions at the ſame diſtance are in the conſtant ratio of m to $m+n$. Therefore the forces are in a conſtant ratio to each other, and their differences are in a conſtant ratio to either of the forces. But the circular force at different diſtances is inverſely as the cube of the diſtance (221). Therefore the difference of them in the fixed and moveable orbits is in the ſame proportion. But the difference of the orbital forces is equal to that of the circular. Therefore, finally, the difference of the centripetal

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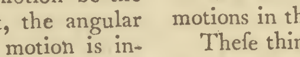

(A) For let Ao, AO, Ac, AC repreſent the four forces o, O, c, and C. By what has been ſaid, we find that $o\,c$=OC. To each of theſe add Oc, and then it is plain that $o\,$O=$c\,$C, that is, that the difference of the circular forces c and C is equal to that of the orbital forces o and O.

petal forces by which a body may be retained in a fixed orbit, and in the ſame orbit moving as determined in article 180, is always in the inverſe triplicate ratio of the diſtances from the centre of forces.

In this example, the motion of the body in the orbit is in the ſame direction with that of the orbit, and the force to be joined with that in the fixed orbit is always additive. Had the orbit moved in the oppoſite direction, the force to be joined would have been ſubtractive, unleſs the retrograde motion of the orbit exceeded twice the angular motion of the body. But in all caſes, the reaſoning is ſimilar.

188. Thus we have conſidered the motions of bodies influenced by forces directed to a fixed point. But we cannot conceive a mere mathematical point of ſpace as the cauſe or occaſion of any ſuch exertion of forces. Such relations are obſerved only between exiſting bodies or maſſes of matter. The propoſitions which have been demonſtrated may be true in relation to bodies placed in thoſe fixed points. That continual tendency towards a centre, which produces an equable deſcription of areas round it, becomes intelligible, if we ſuppoſe ſome body placed in the centre of forces, attracting the revolving body. Accordingly, we ſee very remarkable examples of ſuch tendencies towards a central body in the motions of the planets round the ſun, and of the ſatellites round the primary planet.

But, ſince it is a univerſal fact that all the relations between bodies are mutual, we are obliged to ſuppoſe that whatever force inclines the revolving body towards the body placed in the centre of forces, an equal force (from whatever ſource it is derived) inclines the central body toward the revolving body, and therefore it cannot remain at reſt, but muſt move towards it. The notion of a fixed centre of forces is thus taken away again, and we ſeem to have demonſtrated propoſitions inapplicable to any thing in nature. But more attentive conſideration will ſhew us that our propoſitions are moſt ſtrictly applicable to the phenomena of nature.

189. For, in the firſt place, the motion of the common centre of poſition of two, or of any number of bodies, is not affected by their mutual actions. Theſe, being equal and oppoſite, produce equal and oppoſite motions, or changes of motion. In this caſe, it follows from art. 115. that the ſtate of the common centre is not affected by them.

190. Now, ſuppoſe two bodies S and P, ſituated at the extremities of the line SP (fig. 37.) Their centre of poſition is in a point C, dividing their diſtance in ſuch a manner that SC is to CP as the number of material atoms in P to the number in S or $SC : PC = P : S$. Suppoſe the mutual forces to be centripetal. Then, being equal, exerted between every atom of the one, and every particle of the other, the vis motrix may be expreſſed by $P \times S$. This muſt produce equal quantities of motion in each of the bodies, and therefore muſt produce velocities inverſely as the quantities of matter. In any given portion of time, therefore, the bodies will move towards each other, to s and p, and Ss will be to Pp as P to S, that is, as SC to PC. Therefore we ſhall ſtill have $sC : pC = SC : PC$. Their diſtances from C will always be in the ſame proportion. Alſo we ſhall have $SC : SP = P : S+P$, and $sC : pC = P : S+P$; and therefore $SC : SP = sC : sP$. Conſequently, in whatever manner the mutual forces vary by a variation of diſtance from each other, they will vary in the ſame manner by the ſame variation of diſtance from C. And, converſely, in whatever manner the forces vary by a change of diſtance from C, they vary in the ſame manner by the ſame change of diſtance from each other.

Let us now ſuppoſe that when the bodies are at S and P, equal moving forces are applied to each in the oppoſite directions SA and PB. Did they not attract each other at all, they would, at the end of ſome ſmall portion of time, be found in the points A and B of a ſtraight line drawn through C, becauſe they will move with equal quantities of motion, or with velocities SA and PB inverſely as their quantities of matter. Therefore $SA : PB = SC : PC$, and A, C, and B are in a ſtraight line. But let them now attract, when impelled from S and P. Being equally attracted toward each other, they will deſcribe curve lines Sa and Pb, ſo that their deflections Aa and Bb are as SC and PC; and we ſhall have $aC : bC = SC : PC$. As this is true of every part of the curve, it follows that they deſcribe ſimilar curves round C, which remains in its original place.

Laſtly, If the motion of P be conſidered by an obſerver placed in S, unconſcious of its motion, ſince he judges of the motion of P only by its change of direction and of diſtance, we may make a figure which will perfectly repreſent this motion. Draw the line EF equal and parallel to PS, and EG equal and parallel to ab. Do this for every point of the curve Sa and Pb. We ſhall then form a curve FG ſimilar to the curves Sa and Pb, having the homologous lines equal to the ſum of the homologous lines of theſe two curves. Thus the bodies will deſcribe round each other curve lines which are ſimilar and equal (lineally) to the lines which they deſcribe round their common centre by the ſame forces. They may appear to deſcribe areas proportional to the times round each other; and they really deſcribe areas proportional to the times round their common centre of poſition, and the forces, which really relate to the body which *is ſuppoſed* to be central, have the ſame mathematical relation to their common centre.

Thus it appears that the mechanical inferences, drawn from a ſuppoſed relation to a mere point of ſpace, are true in the real relations to the ſuppoſed central body, although it is not fixed in one place.

191. The time of deſcribing any arch FG of the curve deſcribed round the other body at reſt in a centre of forces (where we may ſuppoſe it forcibly withheld from moving) is to the time of deſcribing the ſimilar arch Pb round the common centre of poſition in the ſubduplicate ratio of $S+P$ to S, that is, in the ratio of $\sqrt{S+P}$ to $\sqrt{S}$. For the forces being the ſame in both motions, the ſpaces deſcribed by their ſimilar actions, that is, their deflections from the tangent, are as the ſquares of the times T and t (204). That is, $HG : Bb = T^2 : t^2$; and $T : t = \sqrt{HG} : \sqrt{Bb}, = \sqrt{S+P} : \sqrt{S}$.

Hence it follows that the two bodies S and P are moved in the ſame way as if they did not act on each other, but were both acted upon by a third body, placed in their common centre C, and acting with the ſame forces on each; and the law of variation of the forces by a change of diſtance from each other, and from this third body, is the ſame.

192. If a body P (fig. 38.) revolve around another

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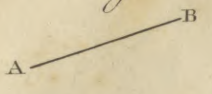
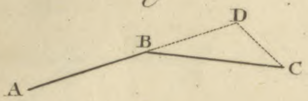


Fig. 2.



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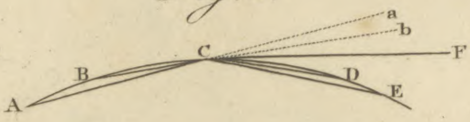

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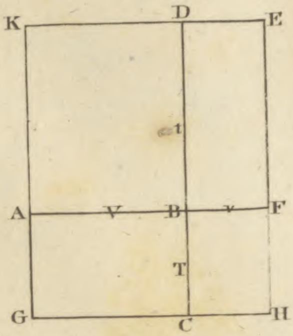

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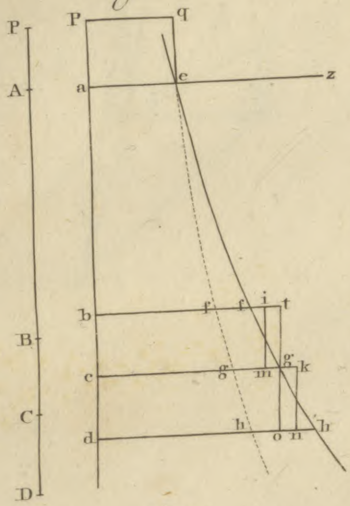

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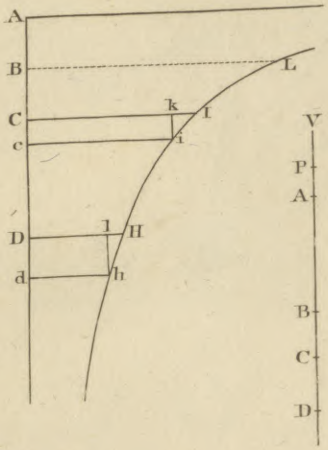

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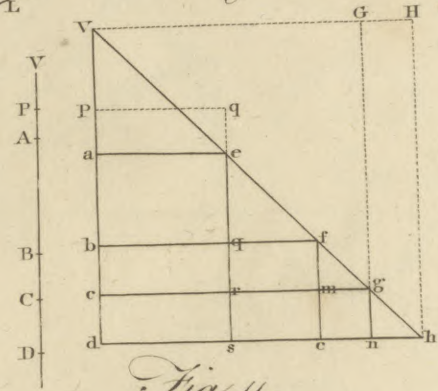

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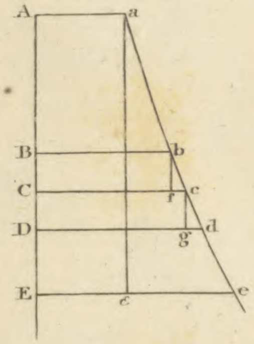

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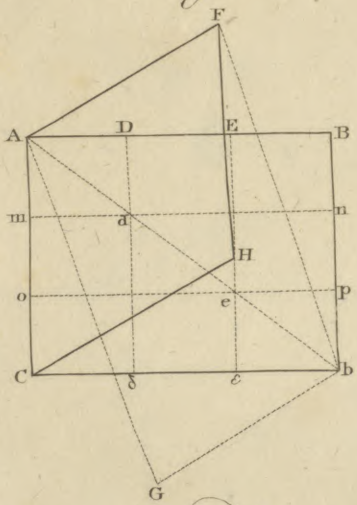

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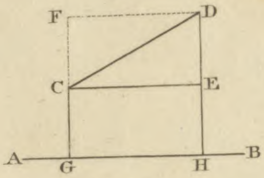

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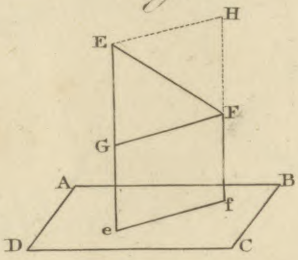

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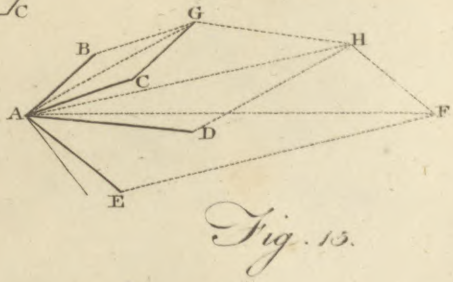

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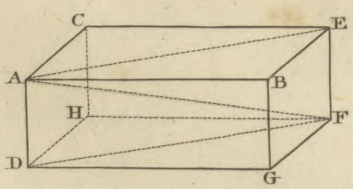

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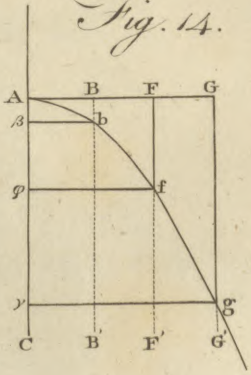

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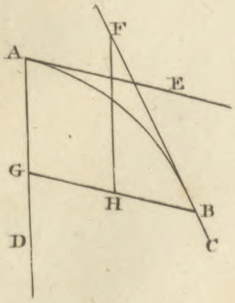

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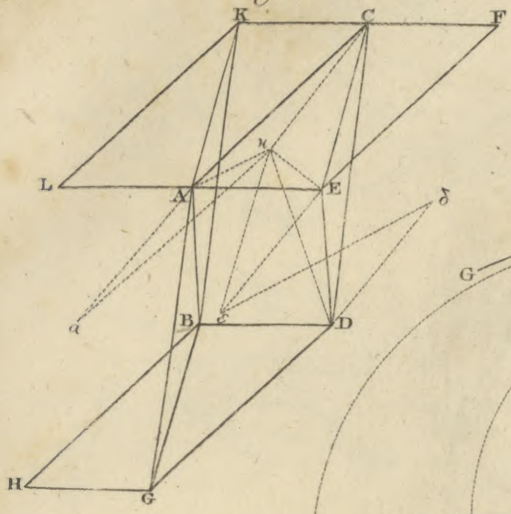

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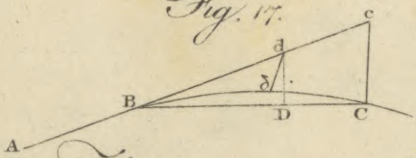

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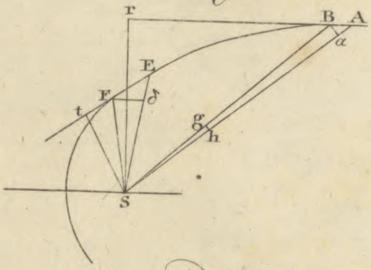

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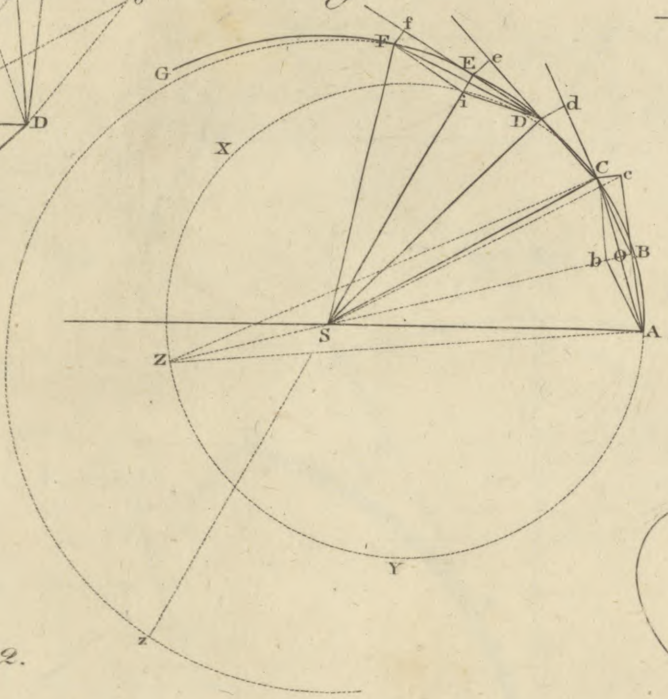

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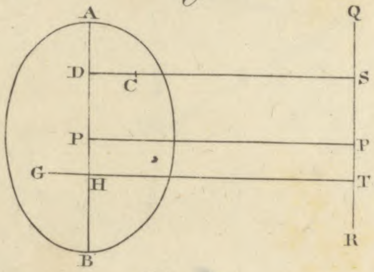

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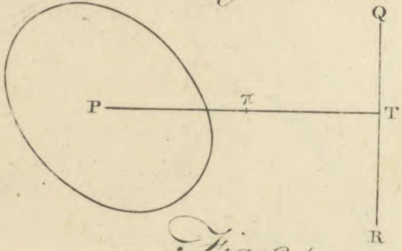

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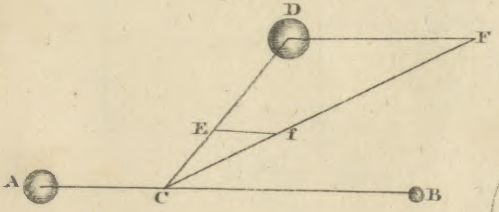

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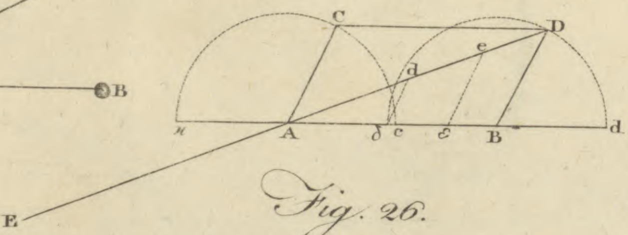

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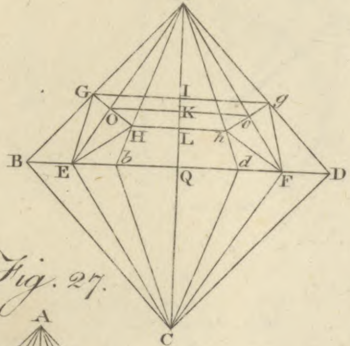

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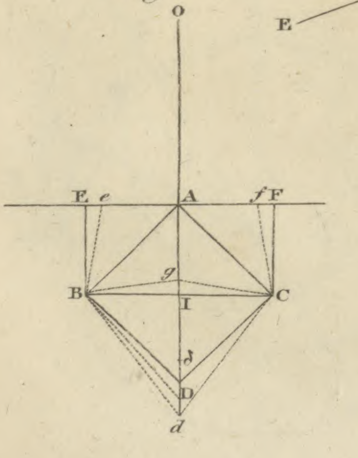

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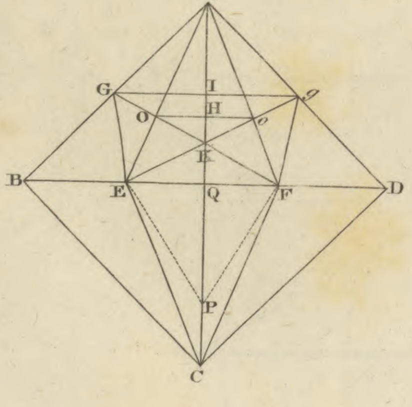

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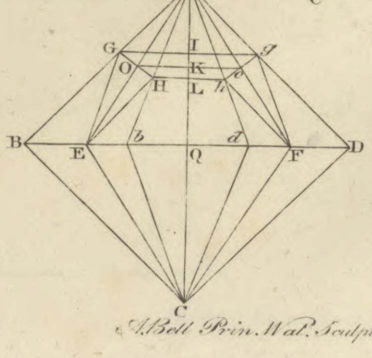

Fig. 27.

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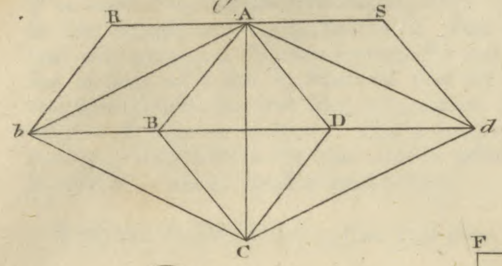
Fig. 28.



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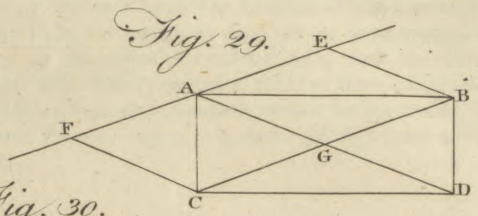

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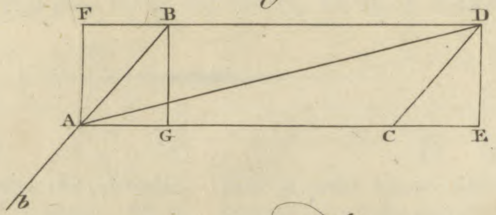

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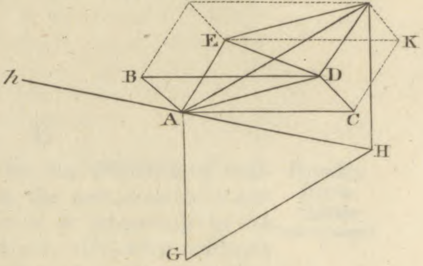

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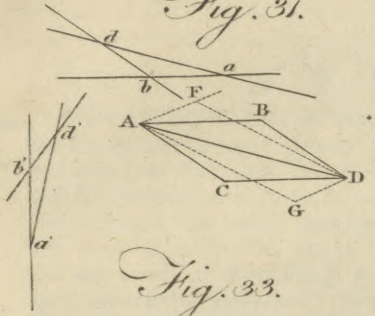

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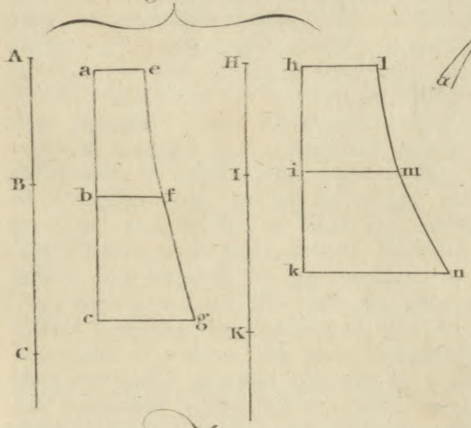

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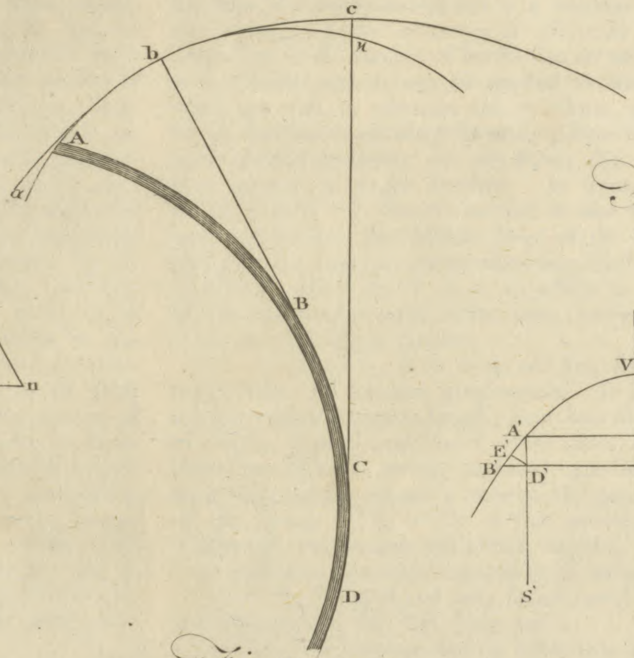

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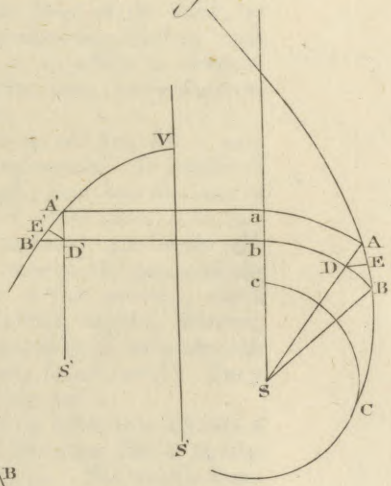

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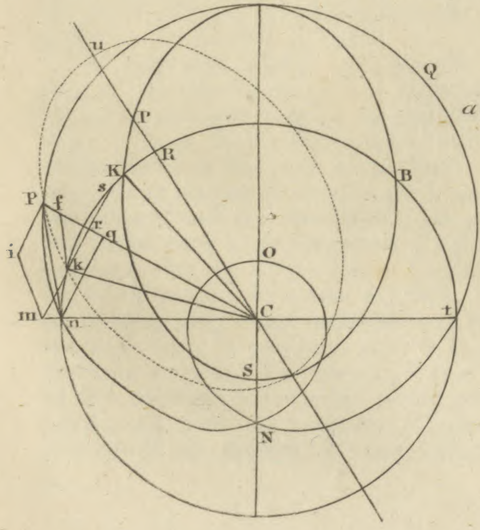

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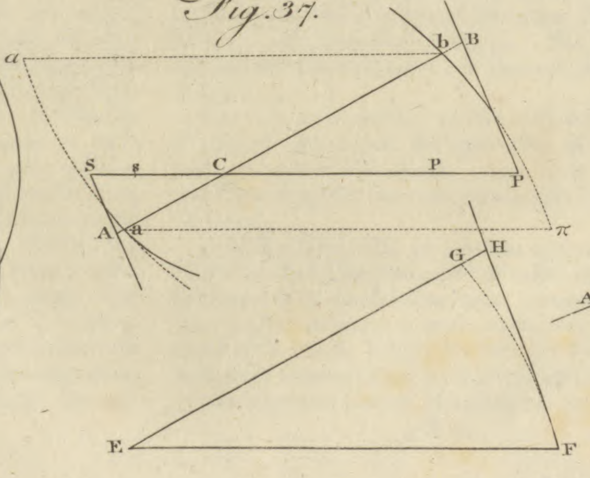

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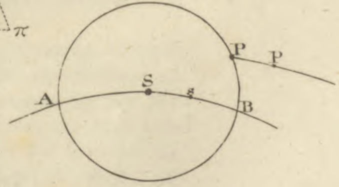

A. Bell Prin. Wal. Sculptor fecit.

Of Moving Forces.

body S, by the action of a central force, while S moves in any path ASB, P will continue to deſcribe areas proportional to the times round S, if every particle in P be affected by the ſame accelerating force that acts, in that inſtant, on every particle in S. For, ſuch action will compound the ſame motions P*p* and S*s* with the motions of S and P, whatever they are; and it was ſhown in art. 69. that ſuch compoſition does not affect their relative motions. This is another way of making a body deſcribe the ſame orbit in motion which it deſcribes while the orbit is fixed (186).

Such is the view of the abſtract doctrines of motion and of moving forces which we propoſed to lay before our readers. Thoſe who have heard the excellent lectures of the late Profeſſor Robiſon of the univerſity of Edinburgh will probably ſee that we have availed ourſelves of his valuable inſtructions; and the learned reader will readily perceive that we have enriched our treatiſe with much important matter by borrowing freely from the writings of the ſame diſtinguiſhed philoſopher.

ERRATUM in DYNAMICS.—*Line 10th from the bottom*, *Col. 1ſt*, *For* fig. 1. *read* fig. 1. Plate CLXXXIV.

Dynanometer.

DYNANOMETER, an inſtrument for aſcertaining the relative ſtrength of men and animals. Of an inſtrument of this kind, invented by Regnier, and of which a deſcription is given in vol. ii. *Jour. de l'Ecole Polytechnique*, the author thus ſpeaks. "Some important knowledge, ſays he, might be acquired, had we the eaſy means of aſcertaining, in a comparative manner, our relative ſtrengths at the different periods of life, and in different ſtates of health. Buffon and Gueneau, who had ſome excellent ideas on this ſubject, requeſted me to endeavour to invent a portable machine, which, by an eaſy and ſimple mechaniſm, might conduct to a ſolution of this queſtion, on which they were then engaged. Theſe philoſophers were acquainted with that invented by Graham, and improved by Dr Deſaguliers, at London; but this machine, conſtructed of wooden-work, was too bulky and heavy to be portable; and, beſides, to make experiments on the different parts of the body, ſeveral machines were neceſſary, each ſuited to the part required to be tried. They were acquainted alſo with the dynanometer of Citizen Leroy of the Academy of Sciences at Paris. It conſiſted of a metal tube 10 or 12 inches 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 out, in degrees, the ſtrength of the perſon who preſſed on the ball with his hand.

This inſtrument, though ingenious, did not appear ſufficient however to Buffon and Gueneau; for they wiſhed not merely to aſcertain the muſcular force of a finger or hand, but to eſtimate that of each limb ſeparately, and of all the parts of the body. I ſhall not here give an account of the attempts I made to fulfil the wiſhes of theſe two philoſophers, but only obſerve, that in the courſe of my experiments I had reaſon to be convinced that the conſtruction of the inſtrument was not ſo eaſy as might have been expected. Beſides the uſe which an enlightened naturaliſt may make of this machine, it may be poſſible to apply it to many other important purpoſes. For example, it may be employed with advantage to determine the ſtrength of draught cattle; and, above all, to try that of horſes, and compare it with the ſtrength of other animals. It may ſerve to make known how far the aſſiſtance of well-conſtructed wheels may favour the movement of a carriage, and what is its *vis inertiæ* in proportion to the load. We might appreciate by it, alſo, what reſiſtance the ſlope of a mountain oppoſes to a carriage, and be able to judge whether a carriage is ſufficiently loaded in proportion to the number of horſes that are to be yoked to it. In the arts, it may be applied to machines of which we wiſh to aſcertain the reſiſtance, and when we are deſirous to calculate the moving force that ought to be adapted to them. It may ſerve, alſo, as a Roman balance to weigh burdens. In ſhort, nothing would be more eaſy than to convert it into an anemometer, to diſcover the abſolute force of the wind, by fitting to it a frame of a determined ſize filled up with wax-cloth; and it would not be impoſſible to aſcertain by this machine the recoil of fire-arms, and conſequently the ſtrength of gun-powder.

This dynanometer, in its form and ſize, has a near reſemblance to a common graphometer. It conſiſts of a ſpring twelve inches in length, bent into the form of an ellipſis; from the middle of which ariſes a ſemicircular piece of braſs, having engraved upon it the different degrees that expreſs a force of the power acting on the ſpring. The whole of this machine, which weighs only two pounds and a half, oppoſes, however, more reſiſtance than may be neceſſary to determine the action of the ſtrongeſt and moſt robuſt horſe." For a fuller deſcription, ſee Phil. Mag. vol. i.

Dynaſty, Dyrrachium.

DYNASTY, among ancient hiſtorians, ſignifies a race or ſucceſſion of kings of the ſame line or family. Such were the dynaſties of Egypt. The word is formed from the Greek δυναϛεια of δυνοϛυω, *to be powerful*, or *king*.

The Egyptians reckon 30 dynaſties within the ſpace of 36,525 years; but the generality of chronologers look upon them as fabulous. And it is very certain, that theſe dynaſties are not continually ſucceſſive, but collateral.

DYRRACHIUM, in *Ancient Geography*, a town on the coaſt of Illyricum, before called *Epidamnum*, or *Epidamnus*, an inauſpicious name, changed by the Romans to *Dyrrachium*; a name taken from the peninſula on which it ſtood. Originally built by the Corcyreans. A Roman colony (Pliny). A town famous in ſtory: its port anſwered to that of Brundusium, and the paſſage between both was very ready and expeditious. It was alſo a very famous mart for the people living on the Adriatic; and the free admiſſion of ſtrangers contributed much to its increaſe: A contraſt to the conduct of the Apollonians; who, in imitation of the Spartans, diſcouraged ſtrangers from ſettling among them.

DYSÆ, in *Mythology*, inferior goddeſſes among the Saxons, being the meſſengers of the great Woden, whoſe province it was to convey the ſouls of ſuch as died in battle to his abode, called *Valhall*, i. e. the hall of ſlaughter; where they were to drink with him and their other gods *cereviſia*, or a kind of malt liquor, in the ſkulls of their enemies. The *Dyſæ* conveyed thoſe who died a natural death to *Hela*, the goddeſs of hell, where they were tormented with hunger, thirſt, and every kind of evil.

DYSCRASY, among phyſicians, denotes an ill habit or ſtate of the humours, as in the ſcurvy, jaundice, &c.

DYSENTERY, in *Medicine*, a diarrhœa or flux, wherein the ſtools are mixed with blood, and the bowels miſerably tormented with gripes. See MEDICINE *Index*.

DYSENTERIC FEVER. *Ibid.*

DYSERT, a parliament town of Scotland, in the county of Fife, ſituated on the northern ſhore of the frith of Forth, about 11 miles north of Edinburgh.

DYSOREXY, among phyſicians, denotes a want of appetite, proceeding from a weakly ſtomach.

DYSPEPSY, a difficulty of digeſtion.

DYSPNOEA, a difficulty of breathing, uſually called *aſthma*. See MEDICINE *Index*.

DYSURY, in *Medicine*, a difficulty of making water, attended with a ſenſation of heat and pain. See MEDICINE *Index*.

DYTISCUS, WATER-BEETLE. See ENTOMOLOGY *Index*.

DYVOUR, in *Scots Law*; otherwiſe *Bare-man*: A perſon who, being involved in debt, and unable to pay the ſame,—for avoiding impriſonment and other pains, makes ceſſion of his effects in favour of his creditors; and does his *devoir* and duty to them, proclaiming himſelf bare-man and indigent, and becoming debt bound to them of all that he has. The word is uſed in the ſame ſenſe as BANKRUPT: ſee that article; and LAW *Index*.

E.

E, THE ſecond vowel, and fifth letter of the alphabet. The letter E is moſt evidently derived from the old character ꓱ in the ancient Hebrew and Phœnician alphabets, inverted by the Greeks to this poſition E, and not from the Hebrew He ה. From the ſame origin is alſo derived the Saxon *e*, which is the firſt letter in their alphabet that differs from the Latin one. It is formed by a narrower opening of the larynx than the letter A; but the other parts of the mouth are uſed nearly in the ſame manner as in that letter.

It has a long and ſhort ſound in moſt languages. The ſhort ſound is audible in *bed*, *fret*, *den*, and other words ending in conſonants: its long ſound is produced by a final *e*, or an *e* at the end of words; as in *glebe*, *here*, *hire*, *ſcene*, *ſphere*, *interfere*, *revere*, *ſincere*, &c. in moſt of which it ſounds like *ee;* as alſo in ſome others by coming after *i*, as in *believe*, *chief*, *grief*, *reprieve*, &c. and ſometimes this long ſound is expreſſed by *ee*, as in *bleed*, *beer*, *creed*, &c. Sometimes the final *e* is ſilent, and only ſerves to lengthen the ſound of the preceding vowel, as in *rag*, *rage*, *ſtag*, *ſtage*, *hug*, *huge*, &c. The ſound of *e* is obſcure in the following words *oxen*, *heaven*, *bounden*, *fire*, *maſſacre*, *maugre*, &c.

The Greeks have their long and ſhort *e* which they call *epſilon* and *eta*. The French have at leaſt ſix kinds of *e*'s: the Latins have likewiſe a long and ſhort *e;* they alſo write *e* inſtead of *a*, as *dicem* for *dicam*, &c. and this is no doubt the reaſon why *a* is ſo often changed into *e* in the preter tenſe, as *ago*, *egi*; *facio*, *feci*, &c.

As a numeral, E ſtands for 250, according to the verſe,

E, *quoque ducentos et quinquaginta tenebit.*

In muſic it denotes the tone *e-la-mi*. In the kalendar it is the fifth of the dominical letters. And in ſea charts it diſtinguiſhes all the eaſterly points: thus, E alone denotes Eaſt; and E. by S. and E. by N. Eaſt by South, and Eaſt by North.

EACHARD, JOHN, an Engliſh divine of great learning and wit in the 17th century, bred at Cambridge, author (in 1670) of *The Grounds and Occaſions of the Contempt of the Clergy and Religion inquired into.* In 1675 he was choſen maſter of Catharine-hall upon the deceaſe of Dr John Lightfoot; and the year following was created D. D. by royal mandate. He died in 1696.

EACHARD, *Laurence*, an eminent Engliſh hiſtorian of the 18th century, nearly related to Dr John Eachard. He was the ſon of a clergyman, who, by the death of his elder brother, became maſter of a good eſtate in Suffolk. He was educated in the univerſity of Cambridge, entered into holy orders, and was preſented to the living of Welton and Elkington in Lincolnſhire; where he ſpent above 20 years of his life, and diſtinguiſhed himſelf by his writings, eſpecially his Hiſtory of England, which was attacked by Dr Edmund Calamy and by Mr John Oldmixon. His "General Eccleſiaſtical Hiſtory from the Nativity of Chriſt to the firſt Eſtabliſhment of Chriſtianity by Human Laws under the emperor Conſtantine the Great," has paſſed through ſeveral editions. He was inſtalled archdeacon

Eadmerus.

of Stowe and prebend of Lincoln in 1712. He died in 1730.

EADMERUS, an eſteemed hiſtorian, was an Engliſhman; but his parents, and the particular time and place of his nativity, are not known. He received a learned education, and very early diſcovered a taſte for hiſtory, by recording every remarkable event that came to his knowledge. Being a monk in the cathedral of Canterbury, he had the happineſs to become the boſom friend and inſeparable companion of two archbiſhops of that ſee, St Anſelm and his ſucceſſor Ralph. To the former of theſe he was appointed ſpiritual director by the pope; and that prelate would do nothing without his permiſſion. In the year 1120, he was ſent for by King Alexander I. of Scotland, to be raiſed to the primacy of that kingdom; and having obtained leave of King Henry and the archbiſhop of Canterbury, he departed for Scotland, where he was kindly received by the king; and on the third day after his arrival, he was elected biſhop of St Andrew's with much unanimity. But on the day after his election, an unfortunate diſpute aroſe between the king and him, in a private conference about his conſecration. Eadmerus having been a conſtant companion of the late and of the preſent archbiſhop of Canterbury, was a violent ſtickler for the prerogatives of that ſee. He therefore told the king, that he was determined to be conſecrated by none but the archbiſhop of Canterbury, who he believed to be the primate of all Britain. Alexander, who was a fierce prince, and ſupported the independency of his crown and kingdom with great ſpirit, was ſo much offended, that he broke off the conference in a violent paſſion, declaring, that the ſee of Canterbury had no pre-eminency over that of St Andrew's. This breach between the king and the biſhop-elect became daily wider, till at length Eadmerus, deſpairing of recovering the royal favour, ſent his paſtoral ring to the king, and laid his paſtoral ſtaff on the high altar, from whence he had taken it, and abandoning his biſhopric returned to England. He was kindly received by the archbiſhop and clergy of Canterbury, though they diſapproved of his ſtiffneſs, and thought him too haſty in forſaking the honourable ſtation to which he had been called. Nor was it long before Eadmerus became ſenſible of his error, and deſirous of correcting it. With this view he wrote a long ſubmiſſive letter to the king of Scotland, entreating his leave to return to his biſhopric, promiſing compliance with his royal pleaſure in every thing reſpecting his conſecration, which was accompanied by an epiſtle to the ſame purpoſe from the archbiſhop. Theſe letters, however, which were written A. D. 1122, did not produce the deſired effect. But Eadmerus is moſt worthy of the grateful remembrance of poſterity for his hiſtorical works, particularly for his excellent hiſtory of the affairs of England in his own time, from A. D. 1066 to A. D. 1122; in which he hath inſerted many original papers, and preſerved many important facts, that are nowhere elſe to be found. This work hath been highly commended, both by ancient and modern writers, for its authenticity, as well as for regularity of compoſition and purity of ſtyle. It is indeed more free from legendary tales than any other work of this period; and it is impoſſible to peruſe it with attention, without conceiving a favourable opinion of the learning, good ſenſe, ſincerity, and candour of its author.

Eagle.

EAGLE. See Falco, Ornithology *Index*.

Eagle, in *Heraldry*, is accounted one of the moſt noble bearings in armoury; and, according to the learned in this ſcience, ought to be given to none but ſuch as greatly excel in the virtues of generoſity and courage, or for having done ſingular ſervices to their ſovereigns; in which caſes they may be allowed a whole eagle, or an eagle naiſſant, or only the head or other parts thereof, as may be moſt agreeable to their exploits.

The eagle has been borne, by way of enſign or ſtandard, by ſeveral nations. The firſt who ſeem to have aſſumed the eagle are the Perſians; according to the teſtimony of Xenophon. Afterwards it was taken by the Romans; who, after a great variety of ſtandards, at length fixed on the eagle, in the ſecond year of the conſulate of C. Marius: till that time, they uſed indifferently wolves, leopards, and eagles, according to the humour of the commander.

The Roman eagles, it muſt be obſerved, were not painted on a cloth or flag; but were figures in relievo, of ſilver or gold, borne on the tops of pikes; the wings being diſplayed, and frequently a thunderbolt in their talons. Under the eagle on the pike, were piled bucklers, and ſometimes crowns. Thus much we learn from the medals.

Conſtantine is ſaid to have firſt introduced the eagle with two heads, to intimate, that though the empire ſeemed divided, it was yet only one body. Others ſay, that it was Charlemagne who reſumed the eagle as the Roman enſign, and added to it a ſecond head; but that opinion is deſtroyed, by an eagle with two heads, noted by Lipſius, on the Antonine column; as alſo by the eagle's only having one head on the ſeal of the golden bull of the emperor Charles IV. The conjecture, therefore, of F. Meneſtrier appears more probable, who maintains, that as the emperors of the Eaſt, when there were two on the throne at the ſame time, ſtruck their coins with the impreſſion of a croſs, with a double traverſe, which each of them held in one hand, as being the ſymbol of the Chriſtians; the like they did with the eagle in their enſigns; and inſtead of doubling their eagles, they joined them together, and repreſented them with two heads. In which they were followed by the emperors of the Weſt.

F. Papebroche wiſhes that this conjecture of Meneſtrier were confirmed by ancient coins; without which, he rather inclines to think the uſe of the eagle with two heads to be merely arbitrary; though he grants it probable, that it was firſt introduced on occaſion of two emperors on the ſame throne.

The eagle on medals, according to M. Spanheim, is a ſymbol of divinity and providence; and, according to all other antiquaries, of empire. The princes on whoſe medals it is moſt uſually found, are the Ptolemies and the Seleucides of Syria. An eagle with the word CONSECRATIO, expreſſes the apotheoſis of an emperor.

Eagles, a name found very frequently in the ancient hiſtories of Ireland, and uſed to expreſs a ſort of baſe money that was current in that kingdom in the firſt

firſt years of the reign of Edward I. that is, about the year 1272. There were, beſides the eagles, lionines, roſades, and many other coins of the ſame ſort, named according to the figures they were impreſſed with.

The current coin of the kingdom was at that time a compoſition of copper and ſilver, in a determined proportion, but theſe were ſo much worſe than the ſtandard proportion of that time, that they were not intrinſically worth quite half ſo much as the others. They were imported out of France and other foreign countries. When this prince had been a few years eſtabliſhed on the throne, he ſet up mints in Ireland for the coining ſufficient quantities of good money, and then decried the uſe of theſe eagles, and other the like kinds of baſe coins, and made it death, with confiſcation of effects, to import any more of them into the kingdom.

EAGLE, in *Aſtronomy*, is a conſtellation of the northern hemiſphere, having its right wing contiguous to the equinoctial. See AQUILA.

There are alſo three ſeveral ſtars, particularly denominated among the Arab aſtronomers, *naſr*, i. e. "eagle." The firſt, *naſr ſohail*, the "eagle of Canopus," called alſo *ſitareh jemen*, the ſtar of Arabia Felix, over which it is ſuppoſed to preſide; the ſecond, *naſr althair*, the "flying eagle;" and the third, *naſr alvoke*, the "reſting eagle."

White EAGLE, is a Poliſh order of knighthood, inſtituted in 1325 by Uladiſlaus V. on marrying his ſon Caſimir with a daughter of the great duke of Lithuania.

The knights of this order were diſtinguiſhed by a gold chain, which they wore on the ſtomach, whereon hung a ſilver eagle crowned.

Black EAGLE, was a like order, inſtituted in 1701 by the elector of Brandenburgh, on his being crowned king of Pruſſia.

The knights of this order wear an orange-coloured ribbon, to which is ſuſpended a black eagle.

EAGLE, in *Architecture*, is a figure of that bird anciently uſed as an attribute, or cognizance of Jupiter, in the capital and friezes of the columns of temples conſecrated to that god.

Eagle-flower. See BALSAMINE.

Eagle-ſtone, in *Natural Hiſtory*, is a ſtone by the Greeks called *ætites*, and by the Italian *pietra d'aquila*, as being ſuppoſed to be ſometimes found in the eagle's neſt. It is of famous traditionary virtue, either for forwarding or preventing the delivery of women in labour, according as it is applied above or below the womb. Matthiolus tells us, that birds of prey could never hatch their young without it, and that they go in ſearch of it as far as the Eaſt Indies. Bauſch has an expreſs Latin treatiſe on the ſubject. See ÆTITES.

EAGLET, a diminutive of eagle, properly ſignifying a young eagle. In heraldry, when there are ſeveral eagles on the ſame eſcutcheon, they are termed *eaglets*.

EALDERMAN, or EALDORMAN, among the Saxons, was of like import with earl among the Danes.

The word was alſo uſed for an elder, ſenator, or ſtateſman. Hence, at this day, we call thoſe *aldermen* who are aſſociates to the chief officer in the common council of a city or corporate town.

EAR. See ANATOMY *Index*.

Several naturaliſts and phyſicians have held, that cutting off the ear rendered perſons barren and unprolific; and this idle notion was what firſt occaſioned the legiſlators to order the ears of thieves, &c. to be cut off, leſt they ſhould produce their like.

The ear has its beauties, which a good painter ought by no means to diſregard; where it is well formed, it would be an injury to the head to be hidden. Suetonius inſiſts, particularly, on the beauties of Auguſtus's ears; and Ælian, deſcribing the beauties of Aſpaſia, obſerves, ſhe had ſhort ears. Martial alſo ranks large ears among the number of the deformities.

Among the Athenians, it was a mark of nobility to have the ears bored or perforated. And among the Hebrews and Romans, this was a mark of ſervitude.

Loſs of one ear is a puniſhment enacted by 5 and 6 Edw. VI. cap. 4. for fighting in a churchyard; and by 2 and 3 Edw. VI. cap. 15. for combinations to raiſe the price of proviſions, labour, &c. if it be the third offence, beſide pillory, and perpetual infamy, or a fine of 40l.

By a ſtatute of Henry VIII. maliciouſly cutting off the ear of a perſon is made a treſpaſs, for which treble damages ſhall be recovered; and the offender is to pay a fine of ten pounds to the king, 37 Hen. VIII. cap. 6. § 4. In the Index to the Statutes at Large, it is ſaid, that this offence may be puniſhed as felony, by 22 and 23 Car. II. cap. 1. § 7. commonly called *Coventry's act*; but ear is not mentioned in that ſtatute.

Ear of Fiſhes. See ANATOMY *Index*.

EAR, in *Muſic*, denotes a kind of internal ſenſe, whereby we perceive and judge of harmony and muſical ſounds. See MUSIC.

In muſic we ſeem univerſally to acknowledge ſomething like a diſtinct ſenſe from the external one of hearing; and call it a *good ear*. And the like diſtinction we ſhould probably acknowledge in other affairs, had we got diſtinct names to denote theſe powers of perception by. Thus a greater capacity of perceiving the beauties of painting, architecture, &c. is called a *fine taſte*.

EAR is alſo uſed to ſignify a long cluſter of flowers or ſeeds, produced by certain plants; uſually called by botaniſts *ſpica*. The flowers and ſeeds of wheat, rye, barley, &c. grow in ears. The ſame holds of the flowers of lavender, &c. We ſay the ſtem of the ear, i. e. its tube or ſtraw; the knot of the ear; the lobes or cells wherein the grains are encloſed; the beard of the ear, &c.

Ear-Ach. See MEDICINE *Index*.

EARING, in the ſea language, is that part of the bolt rope which at the four corners of the ſail is left open, in the ſhape of a ring. The two uppermoſt parts are put over the ends of the yard arms, and ſo the ſail is made faſt to the yard; and into the lowermoſt earings, the ſheets and tacks are ſeized or bent at the clew.

Ear-Pick, an inſtrument of ivory, ſilver, or other metal, ſomewhat in form of a probe, for cleanſing the ear. The Chineſe have a variety of theſe inſtruments, with which they are mighty fond of tickling their ears; but this practice, Sir Hans Sloane obſerves, muſt be very prejudicial to ſo delicate an organ, by bringing too great a flow of humours on it.

Ear-Ring. See PENDENT.

Ear-Wax. See ANATOMY *Index*.

EARWIG. See FORFICULA, ENTOMOLOGY *Index*.

EARL, a Britiſh title of nobility, next below a marquis, and above a viſcount.

The title is ſo ancient, that its original cannot be clearly traced out. This much, however, ſeems tolerably certain, that among the Saxons they were called *ealdormen*, *quaſi* elder men, ſignifying the ſame with *ſenior* or *ſenator* among the Romans; and alſo *ſchiremen*, becauſe they had each of them the civil government of a ſeveral diviſion or ſhire. On the irruption of the Danes they changed their names to *eorels*, which, according to Camden, ſignified the ſame in their language. In Latin they are called *comites*, (a title firſt uſed in the empire), from being the king's attendants; *à ſocietate nomen ſumpſerunt, reges enim tales ſibi aſſociant.* After the Norman conqueſt they were for ſome time called *counts*, or *countées*, from the French; but they did not long retain that name themſelves, though their ſhires are from thence called *counties* to this day. It is now become a mere title: they having nothing to do with the government of the county; which is now entirely devolved on the ſheriff, the earl's deputy, or *vicecomes*. In writs, commiſſions, and other formal inſtruments, the king, when he mentions any peer of the degree of an earl, uſually ſtyles him "truſty and well beloved *couſin*;" an appellation as ancient as the reign of Henry IV.; who being either by his wife, his mother, or his ſiſters, actually related or allied to every earl in the kingdom, artfully and conſtantly acknowledged that connexion in all his letters and other public acts; whence the uſage has deſcended to his ſucceſſors, though the reaſon has long ago failed.

An earl is created by cincture of ſword, mantle of ſtate put upon him by the king himſelf, a cap and a coronet put upon his head, and a charter in his hand.

Earl-Marſhal. See MARSHAL.

EARNEST (ARRHÆ), money advanced to bind the parties to the performance of a verbal bargain. By the civil law, he who recedes from his bargain loſes his earneſt, and if the perſon who received the earneſt give back, he is to return the earneſt double. But with us, the perſon who gave it, is in ſtrictneſs obliged to abide by his bargain; and in caſe he decline it, is not diſcharged upon forfeiting his earneſt, but may be ſued for the whole money ſtipulated.

EARTH, among ancient philoſophers, one of the four elements of which the whole ſyſtem of nature was thought to be compoſed. See ELEMENT.

EARTHS, in *Chemiſtry*, are ſuch ſubſtances as have neither taſte nor ſmell, are incombuſtible, are nearly inſoluble in water, and have a ſpecific gravity under 5. Such are lime, barytes, &c. See CHEMISTRY *Index*.

EARTH, in *Aſtronomy* and *Geography*, one of the primary planets; being this terraqueous globe which we inhabit.

For the aſtronomical facts with regard to the earth, ſee ASTRONOMY; for its geographical hiſtory, ſee GEOGRAPHY; and for the opinions or theories of its formation and changes, ſee GEOLOGY *Index*.

EARTHQUAKE. See GEOLOGY *Index*.

EARTH-WORM. See HELMINTHOLOGY *Index*.

EASEL PIECES, among painters, ſuch ſmall pieces, either portraits or landſcapes, as are painted on the eaſel, i. e. the frame whereon the canvas is laid. They are thus called, to diſtinguiſh them from larger pictures drawn on walls, ceilings, &c.

EASEMENT, in *Law*, a privilege or convenience which one neighbour has of another, whether by charter or preſcription, without profit: ſuch are, a way through his lands, a ſink, or the like. Theſe, in many caſes, may be claimed.

EASING, in the ſea language, ſignifies the ſlackening a rope or the like. Thus, to eaſe the bow line, or ſheet, is to let them go ſlacker; to eaſe the helm, is to let the ſhip go more large, more before the wind, or more larboard.

EAST, one of the four cardinal points of the world; being that point of the horizon where the ſun is ſeen to riſe when in the equinoctial.

The word *eaſt* is Saxon. In Italy, and throughout the Mediterranean, the eaſt wind is called the *levante*: in Greek, ανατολη and απηλιωτης, becauſe it comes from the ſide of the ſun, απ' ἡλιȣ; in Latin *eurus*.

EASTER, a feſtival of the Chriſtian church, obſerved in memory of our Saviour's reſurrection.

The Greeks call it *paſga*, the Latins *paſcha*, a Hebrew word ſignifying *paſſage*, applied to the Jewiſh feaſt of the paſſover. It is called *eaſter* in Engliſh, from the goddeſs Eoſtre, worſhipped by the Saxons with peculiar ceremonies in the month of April.

The Aſiatic churches kept their eaſter upon the very ſame day the Jews obſerved their paſſover, and others on the firſt Sunday after the firſt full moon in the new year. This controverſy was determined in the council of Nice; when it was ordained that eaſter ſhould be kept upon one and the ſame day, which ſhould always be a Sunday, in all Chriſtian churches in the world. For the method of finding eaſter by calculation, ſee CHRONOLOGY.

Easter Iſland, an iſland in the South Sea, lying in N. Lat. 27. 5. W. Long. 109. 46. It is thought to have been firſt diſcovered in 1686 by one DAVIS an Engliſhman, who called it *Davis's Land*. It was next viſited by Commodore Roggewein, a Dutchman, in 1722; who gave it the name of *Eaſter Iſland*, and publiſhed many fabulous accounts concerning the country and its inhabitants. It was alſo viſited by a Spaniſh ſhip in 1770, the captain of which gave it the name of *St Carlos*. The only authentic accounts of this iſland, however, which have yet appeared, are thoſe publiſhed by Captain Cook and Mr Forſter, who viſited it in the month of March 1774. According to theſe accounts, the iſland is about 10 or 12 leagues in circumference, and of a triangular figure; its greateſt length from north-weſt to ſouth-eaſt is about four leagues, and its greateſt breadth two. The hills are ſo high, that they may be ſeen at the diſtance of 15 or 16 leagues. The north and eaſt points of the iſland are of a conſiderable height; between them, on the ſouth-eaſt ſide, the ſhore forms an open bay, in which Captain Cook thinks the Dutch anchored in 1722. He himſelf anchored on the weſt ſide of the iſland, three miles northward.

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ward from the ſouth point. This, he ſays, is a good road with eaſterly winds; but a dangerous one when the wind blows from the contrary quarter, as the other on the ſouth-eaſt ſide muſt be with eaſterly winds: ſo that there is no good accommodation to be had for ſhipping round the whole iſland.

The iſland itſelf is extremely barren; and bears evident marks not only of a volcanic origin, but of having been not very long ago entirely ruined by an eruption. As they approached the ſouth point, Mr Forſter informs us, that they obſerved the ſhore to riſe perpendicularly. It conſiſted of broken rocks, whoſe cavernous appearance, and black or ferruginous colour, ſeemed to indicate that they had been thrown up by ſubterraneous fire. Two detached rocks lie about a quarter of a mile off this point: one of them is ſingular on account of its ſhape, and repreſents a huge column or obeliſk; and both theſe rocks were inhabited by multitudes of ſea fowls. On landing and walking into the country, they found the ground covered with rocks and ſtones of all ſizes, which appeared to have been expoſed to a great fire, where they ſeemed to have acquired a black colour and porous texture. Two or three ſhrivelled ſpecies of graſſes grew among theſe ſtones, and in ſome meaſure ſoftened the deſolate appearance of the country. The farther they advanced, the more ruinous the face of the country ſeemed to be. The roads were intolerably rugged, and filled with heaps of volcanic ſtones, among which the Europeans could not make their way but with the greateſt difficulty; but the natives leaped from one ſtone to another with ſurpriſing agility and eaſe. As they went northward along the iſland, they found the ground ſtill of the ſame nature; till at laſt they met with a rock of large black melted lava, which ſeemed to contain ſome iron, and on which was neither ſoil nor graſs, nor any mark of vegetation. Notwithſtanding this general barrenneſs, however, there are ſeveral large tracts covered with cultivated ſoil, which produces potatoes of a gold yellow colour as ſweet as carrots, plantains, and ſugar canes. The ſoil is a dry hard clay: and the inhabitants uſe the graſs which grows between the ſtones in other parts of the iſland as a manure, and for preſerving their vegetables when young from the heat of the ſun.

The moſt remarkable curioſity belonging to this iſland is a number of coloſſal ſtatues; of which, however, very few remain entire. Theſe ſtatues are placed only on the ſea coaſt. On the eaſt ſide of the iſland were ſeen the ruins of three platforms of ſtone work, on each of which had ſtood four of theſe large ſtatues; but they were all fallen down from two of them, and one from the third: they were broken or defaced by the fall. Mr Wales meaſured one that had fallen, which was 15 feet in length, and ſix broad over the ſhoulders: each ſtatue had on its head a large cylindric ſtone of a red colour, wrought perfectly round. Others were found that meaſured near 27 feet, and upwards of eight feet over the ſhoulders; and a ſtill larger one was ſeen ſtanding, the ſhade of which was ſufficient to ſhelter all the party, conſiſting of near 30 perſons, from the rays of the ſun. The workmanſhip is rude, but not bad, nor are the features of the face ill formed; the ears are long, according to the diſtortion practiſed in the country, and the bodies have hardly any thing of a human figure about them. How theſe iſlanders, wholly unacquainted with any mechanical power, could raiſe ſuch ſtupendous figures, and afterwards place the large cylindric ſtones upon their heads, is truly wonderful! The moſt probable conjecture ſeems to be, that the ſtone is factitious; and that each figure was gradually erected, by forming a temporary platform round it, and raiſing it as the work advanced: but they are at any rate very ſtrong proofs of the ingenuity and perſeverance of the iſlanders in the age when they were built, as well as that the anceſtors of the preſent race had ſeen better days than their deſcendants enjoy. The water of this iſland is in general brackiſh, there being only one well that is perfectly freſh, which is at the eaſt end of the iſland: and whenever the natives repair to it to ſlake their thirſt, they waſh themſelves all over; and if there is a large company, the firſt leaps into the middle of the hole, drinks, and waſhes himſelf without ceremony; after which another takes his place, and ſo on in ſucceſſion. This cuſtom was much diſreliſhed by their new friends, who ſtood greatly in need of this valuable article, and did not wiſh to have it contaminated by ſuch ablutions.

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The people are of a middle ſize. In general they are rather thin; go entirely naked; and have punctures on their bodies, a cuſtom common to all the inhabitants of the South Sea iſlands. Their greateſt ſingularity is the ſize of their ears, the lobe of which is ſtretched out ſo that it almoſt reſts on their ſhoulder; and is pierced with a very large hole, capable of admitting four or five fingers with eaſe. The chief ornaments for their ears are the white down of feathers, and rings which they wear in the inſide of the hole, made of the ſugar cane, which is very elaſtic, and for this purpoſe is rolled up like a watch ſpring. Some were ſeen clothed in the ſame cloth uſed in the iſland of Otaheite, tinged of a bright orange colour with turmeric; and theſe our voyagers ſuppoſed to be chiefs. Their colour is a cheſnut brown; their hair black, curling, and remarkably ſtrong; and that on the head as well as the face is cut ſhort. The women are ſmall, and ſlender limbed: they have punctures on the face, reſembling the patches ſometimes uſed by European ladies; they paint their face all over with a reddiſh brown ruddle, and above this they lay a fine orange colour extracted from turmeric root; the whole is then variegated with ſtreaks of white ſhell lime. But the moſt ſurpriſing circumſtance of all with regard to theſe people, is the apparent ſcarcity of women among them. The niceſt calculation that could be made, never brought the number of inhabitants in this iſland to above 700, and of theſe the females bore no proportion in number to the males. Either they have but few females, or elſe their women were reſtrained from appearing during the ſtay of the ſhip; notwithſtanding, the men ſhowed no ſigns of a jealous diſpoſition, or the women any ſcruples of appearing in public: in fact, they ſeemed to be neither reſerved nor chaſte; and the large pointed cap which they wore gave them the appearance of profeſſed wantons. But as all the women who were ſeen were liberal of their favours, it is more than probable that all the married and modeſt ones had concealed themſelves from their impetuous viſitants in ſome inſcrutable parts of the iſland; and what further ſtrengthens this ſuppoſition is, that

that heaps of ſtones were ſeen piled up into little hillocks, which had one ſteep perpendicular ſide, where a hole went under ground. The ſpace within, ſays Mr Forſter, could be but ſmall; and yet it is probable that theſe cavities ſerved, together with their miſerable huts, to give ſhelter to the people at night; and they may communicate with natural caverns, which are very common in the lava currents of volcanic countries. The few women that appeared were the moſt laſcivious of their ſex perhaps that have been ever noticed in any country; ſhame ſeemed to be entirely unknown to them.

EATON, a town of Buckinghamſhire, ſituated on the north ſide of the Thames, oppoſite to Windſor, and famous for its collegiate ſchool, founded by King Henry VI. being a ſeminary for King's College, Cambridge, the fellows of which are all from this ſchool. See ETON.

EAU DE CARMES. See PHARMACY.

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 Nicolſon, 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 do not ſucceed, and that the uſe of maſtic in it has hitherto been kept a ſecret, he made the following trials to procure a good eau de luce.

One dram of the rectified oil of amber was diſſolved in four ounces of the ſtrongeſt ardent ſpirit of the ſhops; its ſpecific gravity being .840 at 60 degrees of Fahrenheit. A portion of the clear ſpirit was poured upon a larger quantity of fine powdered maſtic than it was judged could be taken up. This was occaſionally agitated without heat; by which means the gum reſin was for the moſt part gradually diſſolved. One part of the oily ſolution was poured into a phial, and to this was added one part of the ſolution of maſtic. No opacity or other change appeared. Four parts of ſtrong cauſtic volatile alkali were then poured in, and immediately ſhaken. The fluid was of a denſe opaque white colour, affording a ſlight ruddy tinge when the light was ſeen through a thin portion of it. In a ſecond mixture, four parts of the alkali were added to one of the ſolution of maſtic; it appeared of a leſs denſe and more yellowiſh white than the former mixture. More of the gum reſinous ſolution was then poured in; but it ſtill appeared leſs opaque than that mixture. It was ruddy 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. 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 employed to give the liquor the proper degree of opacity."

EAVES, in *Architecture*, the margin or edge of the roof of a houſe; being the loweſt tiles, ſlates, or the like, that hang over the walls, to throw off water to a diſtance from the wall.

Eaves-Droppers, are ſuch perſons as ſtand under the eaves, or walls, and windows of a houſe, by night or day, to hearken after news, and carry it to others, and thereby cauſe ſtrife and contention in the neighbourhood. They are called *evil members of the commonwealth* by the ſtat. of Weſt. 1. c. 33. They may be puniſhed either in the court leet by way of preſentment and fine, or in the quarter ſeſſions by indictment and binding to good behaviour.

EBBING OF THE TIDES. See TIDE.

EBDOMARIUS, in eccleſiaſtical writers, an officer formerly appointed weekly to ſuperintend the performance of divine ſervice in cathedrals, and preſcribe the duties of each perſon attending in the choir, as to reading, ſinging, praying, &c. To this purpoſe the ebdomary, at the beginning of his week, drew up in form a bill or writing of the reſpective perſons, and their ſeveral offices, called *tabula*, and the perſons there entered were ſtyled *intabulati*.

EBDOME, Εβδομη, in antiquity, a feſtival kept on the ſeventh of every lunar month, in honour of Apollo, to whom all ſeventh days were ſacred, becauſe one of them was his birth-day; whence he was ſometimes called *Ebdomagenes*. For the ceremonies of this ſolemnity ſee *Potter's Archæol. Græc.* lib. ii. cap. 20.

EBENUS, the EBONY TREE. See BOTANY *Index*.

EBION, the author of the hereſy of the EBIONITES, was a diſciple of Cerinthus, and his ſucceſſor. He improved upon the errors of his maſter, and added to them new opinions of his own. He began his preaching in Judea: he taught in Aſia, and even at Rome. His tenets infected the iſle of Cyprus. St John oppoſed both Cerinthus and Ebion in Aſia; and it is thought, that this apoſtle wrote his goſpel, in the year 97, particularly againſt this hereſy.

EBIONITES, ancient heretics, who roſe in the church in the very firſt age thereof, and formed themſelves into a ſect in the ſecond century, denying the divinity of Jeſus Chriſt.

Origen takes them to have been ſo called from the Hebrew word *ebion*, which in that language ſignifies *poor;* becauſe, ſays he, they were poor in ſenſe, and wanted underſtanding. Euſebius, with a view to the ſame etymology, is of opinion they were thus called, as having poor thoughts of Jeſus Chriſt, taking him for no more than a mere man.

It is more probable the Jews gave this appellation to the Chriſtians in general out of contempt; becauſe in the firſt times there were few but poor people that embraced the Chriſtian religion. This opinion Origen himſelf ſeems to give into, in his book againſt Celſus, where he ſays that they called *Ebionites*, ſuch among the Jews as believed that Jeſus was truly the expected Meſſiah.

It might even be urged, with ſome probability, that the primitive Chriſtians aſſumed the name themſelves, in conformity to their profeſſion. It is certain, Epiphanius obſerves, they valued themſelves on being poor, in imitation of the apoſtles. The ſame Epiphanius, however, is of opinion, that there had been a man of the name of EBION, the chief and founder of the ſect of Ebionites, contemporary with the Nazarenes and Cerinthians. He gives a long and exact account of the origin of the Ebionites, making them to have riſen after the deſtruction of Jeruſalem, when the firſt Chriſtians, called *Nazarenes*, went out of the ſame to live at Pella.

The Ebionites were little elſe than a branch of Nazarenes: only that they altered and corrupted in many things the purity of the faith held among thoſe firſt adherents to Chriſtianity. For this reaſon Origen diſtinguiſhes two kinds of Ebionites, in his anſwer to Celſus; the one believed that Jeſus Chriſt was born of a virgin; and the other, that he was born after the manner of other men.

The firſt were orthodox in every thing, except that to the Chriſtian doctrine they joined the ceremonies of the Jewiſh law, with the Jews, Samaritans, aud Nazarenes; together with the traditions of the Phariſees. They differed from the Nazarenes, however, in ſeveral things, chiefly as to what regards the authority of the ſacred writings; for the Nazarenes received all for Scripture contained in the Jewiſh canon; whereas the Ebionites rejected all the prophets, and held the very names of David, Solomon, Iſaiah, Jeremiah, and Ezekiel, in abhorrence. They alſo rejected all St Paul's epiſtles, whom they treated with the utmoſt diſreſpect.

They received nothing of the Old Teſtament but the Pentateuch; which ſhould intimate them to have deſcended rather from the Samaritans than from the Jews. They agreed with the Nazarenes in uſing the Hebrew goſpel of St Matthew, otherwiſe called the Goſpel of the Twelve Apoſtles; but they had corrupted their copy in abundance of places; and particularly, had left out the genealogy of our Saviour, which was preſerved entire in that of the Nazarenes, and even in thoſe uſed by the Cerinthians.

Some, however, have made this goſpel canonical, and of greater value than our preſent Greek goſpel of St Matthew: See NAZARENES. Theſe laſt, whoſe ſentiments, as to the birth of our Saviour, were the ſame with thoſe of the Ebionites, built their error on this very genealogy.

Beſides the Hebrew goſpel of St Matthew, the Ebionites had adopted ſeveral other books, under the names of St James, John, and the other apoſtles: they alſo made uſe of the Travels of St Peter, which are ſuppoſed to have been written by St Clement; but had altered them ſo, that there was ſcarce any thing of truth left in them. They even made that ſaint tell a number of falſehoods, the better to authoriſe their own practices. See St Epiphanius, who is very diffuſive on the ancient hereſy of the Ebionites, *Hær.* 30. But his account deſerves little credit, as, by his own confeſſion, he has confounded the other ſects with the Ebionites, and has charged them with errors to which the firſt adherents of this ſect were utter ſtrangers.

EBONY OF CRETE. See EBENUS, BOTANY *Index*.

EBONY Wood is brought from the Indies, exceedingly hard and heavy, ſuſceptible of a very fine poliſh, and on that account uſed in moſaic and inlaid works, toys, &c. There are divers kinds of ebony; the moſt uſual among us are black, red, and green, all of them the product of the iſland of Madagaſcar, where the natives call them differently *hazon mainthi*, q. d. *black wood*. The iſland of St Maurice, belonging to the Dutch, likewiſe furniſhes part of the ebonies uſed in Europe.

Authors and travellers give very different accounts of the tree that yields the black ebony. By ſome of their deſcriptions, it ſhould be a ſort of palm tree; by others a cytiſus, &c. The moſt authentic of them is that of M. Falcourt, who reſided many years in Madagaſcar as governor thereof; he aſſures us, that it grows very high and big, its bark being black, and its leaves reſembling thoſe of our myrtle, of a deep duſky green colour.

Tavernier aſſures us, that the iſlanders always take care to bury their trees, when cut down, to make them the blacker, and to prevent their ſplitting when wrought. F. Plumier mentions another black ebony tree, diſcovered by him at St Domingo, which he calls *ſpartium portulacæ foliis aculeatum ebeni materiæ*. Candia alſo bears a little ſhrub, known to the botaniſts under the name of *EBENUS Cretica*, above deſcribed.

Pliny and Dioſcorides ſay the beſt ebony comes from Ethiopia, and the worſt from India; but Theophraſtus prefers that of India. Black ebony is much preferred to that of other colours. The beſt is a jet black, free of veins and rind, very maſſive, aſtringent, and of an acrid pungent taſte. Its rind, infuſed in water, is ſaid to purge pituita, and cure venereal diſorders; whence Matthiolus took guaiacum for a ſort of ebony. It yields an agreeable perfume when laid on burning coals: when green, it readily takes fire from the abundance of its fat. If rubbed againſt a ſtone, it becomes brown. The Indians make ſtatues of their gods, and ſceptres for their princes, of this wood. It was firſt brought to Rome by Pompey, after he ſubdued Mithridates. It is now much leſs uſed among us than anciently, ſince the diſcovery of ſo many ways of giving other hard woods a black colour.

As to the green ebony, beſides Madagaſcar and St Maurice, it likewiſe grows in the Antilles, and eſpecially in the iſle of Tobago. The tree that yields it is very buſhy; its leaves are ſmooth, and of a fine green colour. Beneath its bark is a white blea, about two inches thick; all beneath which, to the very heart, is a deep green, approaching towards a black, though ſometimes ſtreaked with yellow veins. Its uſe is not confined

confined to moſaic work: it is likewiſe good in dyeing, as yielding a fine green tincture. As to red ebony, called alſo *grenadilla*, we know little of it more than the name.

The cabinet-makers, inlayers, &c. make pear tree and other woods paſs for ebony, by giving them the black colour thereof. This ſome do by a few waſhes of a hot decoction of galls; and when dry, adding writing ink thereon, and poliſhing it with a ſtiff bruſh, and a little hot wax; and others heat or burn their wood black.

EBORACUM, in *Ancient Geography*, a famous city of the Brigantes in Britain, the reſidence of Septimius Severus and Conſtantius Chlorus, and where they both died; a Roman colony; and the ſtation of the Legio Sexta Victrix. Now *York*. W. Long. 50. Lat. 54. *Caer-frock* or *Caer-effroc*, in Britiſh (Camden).

EBRO, anciently IBERUS, a large river of Spain, which, taking its riſe in Old Caſtile, runs through Biſcay and Arragon, paſſes by Saragoſſa, and, continuing its courſe through Catalonia, diſcharges itſelf with great rapidity into the Mediterranean, about 20 miles below the city of Tortoſa.

EBUDÆ, or HEBUDES, in *Ancient Geography*, iſlands on the weſt of Scotland. The ancients differ greatly as to their ſituation, number and names; ſaid in general to lie to the north of Ireland and weſt of Scotland. Now called the *Weſtern Iſles*, alſo *Hebrides;* this laſt a modern name, the reaſon of which does not appear, unleſs it be a corruption of *Hebudes*. By Beda called *Mevaniæ*, an appellation equally obſcure.

EBULLITION, the ſame with BOILING. The word is alſo uſed in a ſynonymous ſenſe with EFFERVESCENCE.

EBUSUS, in *Ancient Geography*, the greater of the two iſlands called Pityuſæ, in the Mediterranean, near the eaſt coaſt of Spain, to the ſouth-weſt of Majorca. Famous for its paſtures for cattle, and for its figs. Now *Ivica*, 100 miles in compaſs, without any noxious animals but rabbits, who often deſtroy the corn.

ECALESIA, Εκαλησια, in antiquity, a feſtival kept in honour of Jupiter, ſurnamed *Hecalus*, or *Hecaleſius*, from *Hecale*, one of the borough towns in Attica.

ECASTOR, in antiquity, an oath wherein Caſtor was invoked. It was a cuſtom for the men never to ſwear by Caſtor, nor the women by Pollux.

ECATEA, Εκαταια, in antiquity, ſtatues erected to the goddeſs Hecate, for whom the Athenians had a great veneration, believing that ſhe was the overſeer of their families, and that ſhe protected their children.

ECATESIA, Εκατησια, in antiquity, an anniverſary ſolemnity, obſerved by the Stratonicenſians, in honour of Hecate. The Athenians likewiſe had a public entertainment or ſupper every new moon, in honour of the ſame goddeſs. The ſupper was provided at the charge of the richer ſort; and was no ſooner brought to the accuſtomed place but the poor people carried all off, giving out that Hecate had devoured it. For the reſt of the ceremonies obſerved on this occaſion, ſee *Pott. Arch. Græc.* lib. ii. cap. 20.

ECATOMBÆON, Εκατομβαιων, in *Chronology*, the firſt month of the Athenian year. It conſiſted of 30 days, and began on the firſt new moon after the ſummer ſolſtice, and conſequently anſwered to the latter part of our June and beginning of July. The Bœotians called it *Hippodromus*, and the Macedonians *Lous*. See MONTH. The word is a derivative from the Greek ἑκατομβη, *a hecatomb*, becauſe of the great number of hecatombs ſacrificed in it.

ECAVESSADE, in the manege, is uſed for a jerk of the caveſſon.

ECBATANA, in *Ancient Geography*, the royal reſidence and the capital of Media, built by Deioces king of the Medes, according to Herodotus: Pliny ſays, by Seleucus; but that could not be, becauſe it is mentioned by Demoſthenes. It was ſituated on a gentle declivity, diſtant 12 ſtadia from Mount Orontes, and was in compaſs 150 ſtadia. Here ſtood the royal treaſury and tombs. It was an open unwalled town, but had a very ſtrong citadel, encompaſſed with ſeven walls, one within and riſing above another. The extent of the outmoſt was equal to the whole extent of Athens, according to Herodotus; the ſituation favouring this conſtruction, as being a gentle aſcent, and each wall was of a different colour.—Another *Ecbatana* of Perſia, a town of the Magi (Pliny).—A third of Syria.

ECCENTRICITY. See EXCENTRICITY.

ECCHELLENSIS, ABRAHAM, a learned Maronite, whom the preſident Le Jai employed in the edition of his Polyglott Bible. Gabriel Sionita, his countryman, drew him to Paris, in order to make him his fellow labourer in publiſhing that Bible. They fell out; Gabriel complained to the parliament, and cruelly defamed his aſſociate; their quarrel made a great noiſe. The congregation *de propaganda fide* aſſociated him, 1636, with thoſe whom they employed in making an Arabic tranſlation of the Scriptures. They recalled him from Paris, and he laboured in that tranſlation at Rome in the year 1652. While he was profeſſor of the Oriental languages at Rome, he was pitched upon by the great duke Ferdinand II. to tranſlate from Arabic into Latin the 5th, 6th, and 7th books of Apollonius's Conics; in which he was aſſiſted by John Alphonſo Borelli, who added commentaries to them. He died at Rome in 1644.

ECCHYMOSIS, from εκχυω, to *pour out*, or from ἐξ, *out of*, and χυμος, *juice*. It is an effuſion of humours from their reſpective veſſels, under the integuments; or, as Paulus Ægineta ſays, "When the fleſh is bruiſed by the violent colliſion of any object, and its ſmall veins broken, the blood is gradually diſcharged from them." This blood, when collected under the ſkin, is called *ecchymoſis*, the ſkin in the mean time remaining entire; ſometimes a tumour is formed by it, which is ſoft and livid, and generally without pain. If the quantity of blood is not conſiderable, it is uſually reſorbed; if much, it ſuppurates: it rarely happens that any further inconvenience follows; though, in caſe of a very bad habit of body, a mortification may be the reſult, and in ſuch caſe regard muſt be had thereto.

ECCLAIRCISSEMENT. See ESCLAIRCISSEMENT.

ECCLESIASTES, a canonical book of the Old Teſtament, the deſign of which is to ſhow the vanity of all ſublunary things.

It was compoſed by Solomon; who enumerates the ſeveral objects on which men place their happineſs, and then ſhows the inſufficiency of all worldly enjoyments.

The Talmudiſts made King Hezekiah to be the author of it: Grotius aſcribes it to Zorobabel, and others to Iſaiah; but the generality of commentators believe this book to be the produce of Solomon's repentance, after having experienced all the follies and pleaſures of life.

ECCLESIASTICAL, an appellation given to whatever belongs to the church: thus we ſay, eccleſiaſtical polity, juriſdiction, hiſtory, &c.

Blackſtone's Comment.

Ecclesiastical Courts. In the time of the Anglo-Saxons there was no ſort of diſtinction between the lay and the eccleſiaſtical juriſdiction: the county court was as much a ſpiritual as a temporal tribunal: the rights of the church were aſcertained and aſſerted at the ſame time, and by the ſame judges, as the rights of the laity. For this purpoſe the biſhop of the dioceſe, and the alderman, or in his abſence the ſheriff of the county, uſed to ſit together in the county court, and had there the cognizance of all cauſes as well eccleſiaſtical as civil; a ſuperior deference being paid to the biſhop's opinion in ſpiritual matters, and to that of the lay judges in temporal. This union of power was very advantageous to them both: the preſence of the biſhop added weight and reverence to the ſheriff's proceedings; and the authority of the ſheriff was equally uſeful to the biſhop, by enforcing obedience to his decrees in ſuch refractory offenders as would otherwiſe have deſpiſed the thunder of mere eccleſiaſtical cenſures.

But ſo moderate and rational a plan was wholly inconſiſtent with thoſe views of ambition that were then forming by the court of Rome. It ſoon became an eſtabliſhed maxim in the papal ſyſtem of policy, that all eccleſiaſtical perſons, and all eccleſiaſtical cauſes, ſhould be ſolely and entirely ſubject to eccleſiaſtical juriſdiction only: which juriſdiction was ſuppoſed to be lodged in the firſt place and immediately in the Pope, by divine indefeaſible right and inveſtiture from Chriſt himſelf, and derived from the Pope to all inferior tribunals. Hence the canon law lays it down as a rule, that "*ſacerdotes à regibus honorandi ſunt, non judicandi;* and places an emphatical reliance on a fabulous tale which it tells of the emperor Conſtantine, That when ſome petitions were brought to him, imploring the aid of his authority againſt certain of his biſhops accuſed of oppreſſion and injuſtice; he cauſed, (ſays the holy canon) the petitions to be burnt in their preſence, diſmiſſing them with this valediction: "*Ite, et inter vos cauſas veſtras diſcutite, quia dignum non eſt ut nos judicemus Deos.*

It was not, however, till after the Norman conqueſt, that this doctrine was received in England; when William I. (whoſe title was warmly eſpouſed by the monaſteries which he liberally endowed, and by the foreign clergy whom he brought over in ſhoals from France and Italy, and planted in the beſt preferments of the Engliſh church) was at length prevailed upon to eſtabliſh this fatal encroachment, and ſeparate the eccleſiaſtical court from the civil: whether actuated by principles of bigotry, or by thoſe of a more refined policy, in order to diſcountenance the laws of King Edward abounding with the ſpirit of Saxon liberty, is not altogether certain. But the latter, if not the cauſe, was undoubtedly the conſequence, of this ſeparation: for the Saxon laws were ſoon overborne by the Norman juſticiaries, when the county court fell into diſregard by the biſhop's withdrawing his preſence, in obedience to the charter of the conqueror; which prohibited any ſpiritual cauſe from being tried in the ſecular courts, and commanded the ſuitors to appear before the biſhop only, whoſe deciſions were directed to conform to the canon law.

King Henry I. at his aceſſion, among other reſtorations of the laws of King Edward the Confeſſor, revived this of the union of the civil and eccleſiaſtical courts. Which was, according to Sir Edward Coke, after the great heat of the conqueſt was paſt, only a reſtitution of the ancient law of England. This however was ill reliſhed by the Popiſh clergy, who, under the guidance of that arrogant prelate Archbiſhop Anſelm, very early diſapproved of a meaſure that put them on a level with the profane laity, and ſubjected ſpiritual men and cauſes to the inſpection of the ſecular magiſtrates: and therefore, in their ſynod at Weſtminſter, 3 Hen. I. they ordained, that no biſhop ſhould attend the diſcuſſion of temporal cauſes; which ſoon diſſolved this newly effected union. And, when upon the death of King Henry I. the uſurper Stephen was brought in and ſupported by the clergy, we find one article of the oath which they impoſed upon him was, that eccleſiaſtical perſons and eccleſiaſtical cauſes ſhould be ſubject only to the biſhop's juriſdiction. And as it was about that time that the conteſt and emulation began between the laws of England and thoſe of Rome, the temporal courts adhering to the former, and the ſpiritual adopting the latter, as their rule of proceeding; this widened the breach between them, and made a coalition afterwards impracticable; which probably would elſe have been effected at the general reformation of the church.

Eccleſiaſtical courts are various; as the Archdeacon's, the Consistory, the court of Arches, the Peculiars, the Prerogative, and the great court of appeal in all eccleſiaſtical cauſes, viz. the Court of Delegates. See theſe articles.

Blackſtone's Comment.

As to the method of proceeding in the ſpiritual courts, it muſt (in the firſt place) be acknowledged to their honour, that though they continue to this day to decide many queſtions which are properly of temporal cognizance, yet juſtice is in general ſo ably and impartially adminiſtered, in thoſe tribunals (eſpecially of the ſuperior kind), and the boundaries of their power are now ſo well known and eſtabliſhed, that no material inconvenience at preſent ariſes from this juriſdiction ſtill continuing in the ancient channel. And, ſhould any alteration be attempted, great confuſion would probably ariſe, in overturning long eſtabliſhed forms, and new-modelling a courſe of proceedings that has now prevailed for ſeven centuries.

The eſtabliſhment of the civil law proceſs in all the eccleſiaſtical courts was indeed a maſterpiece of papal diſcernment, as it made a coalition impracticable between them and the national tribunals, without manifeſt inconvenience and hazard. And this conſideration had undoubtedly its weight in cauſing this meaſure to be adopted, though many other cauſes concurred. In particular, it may be here remarked, that the Pandects, or or collections of civil law, being written in the Latin tongue, and referring ſo much to the will of the prince and his delegated officers of juſtice, ſufficiently recommended them to the court of Rome, excluſive of their intrinſic merit. To keep the laity in the darkeſt ignorance, and to monopolize the little ſcience which then exiſted entirely among the monkiſh clergy, were deep-rooted principles of papal policy. And as the biſhops of Rome affected in all points to mimic the imperial grandeur, as the ſpiritual prerogatives were moulded on the pattern of the temporal, ſo the canon law proceſs was formed on the model of the civil law; the prelates embracing, with the utmoſt ardour, a method of judicial proceedings, which was carried on in a language unknown to the bulk of the people, which baniſhed the intervention of a jury (that bulwark of Gothic liberty), and which placed an arbitrary power of deciſion in the breaſt of a ſingle man.

The proceedings in the eccleſiaſtical courts are therefore regulated according to the practice of the civil and canon laws; or rather to a mixture of both, corrected and new-modelled by their own particular uſages, and the interpoſition of the courts of common law. For, if the proceedings in the ſpiritual court be ever ſo regularly conſonant to the rules of the Roman law, yet if they be manifeſtly repugnant to the fundamental maxims of the municipal laws, to which, upon principles of ſound policy, the eccleſiaſtical proceſs ought in every ſtate to conform (as if they require two witneſſes to prove a fact, where one will ſuffice at common law); in ſuch caſes, a prohibition will be awarded againſt them. But, under theſe reſtrictions, their ordinary courſe of proceeding is, firſt, by *citation*, to call the party injuring before them. Then by *libel* (*libellus*, "a little book"), or by articles drawn out in a formal *allegation*, to ſet forth the complainant's ground of complaint. To this ſucceeds the *defendant's anſwer* upon oath; when, if he denies or extenuates the charge, they proceed to *proofs* by witneſſes examined, and their depoſitions taken down in writing by an officer of the court. If the defendant has any circumſtances to offer in his defence, he muſt alſo propound them in what is called his *defenſive allegation*, to which he is entitled in his turn to the *plaintiff's anſwer* upon oath, and may from thence proceed to *proofs* as well as his antagoniſt. The canonical doctrine of *purgation*, whereby the parties were obliged to anſwer upon oath to any matter, however criminal, that might be objected againſt them (though long ago overruled in the court of chancery, the genius of the Engliſh law having broken through the bondage impoſed on it by its clerical chancellors, and aſſerted the doctrines of judicial as well as civil liberty), continued till the middle of the laſt century to be upheld by the ſpiritual courts; when the legiſlature was obliged to interpoſe, to teach them a leſſon of ſimilar moderation. By the ſtatute of 13 Car. II. c. 12. it is enacted, that it ſhall not be lawful for any biſhop, or eccleſiaſtical judge, to tender or adminiſter to any perſon whatſoever, the oath uſually called the oath *ex officio*, or any other oath whereby he may be compelled to confeſs, accuſe, or purge himſelf of any criminal matter or thing, whereby he may be liable to any cenſure or puniſhment. When all the pleadings and proofs are concluded, they are referred to the conſideration, not of a jury, but of a ſingle judge; who *takes information* by hearing advocates on both ſides, and thereupon forms his *interlocutory decree* or *definitive ſentence*, at his own diſcretion, from which there generally lies an *appeal*, in the ſeveral ſtages mentioned in the articles above referred to; though, if the ſame be not appealed from him in 15 days, it is final, by the ſtatute 25 Henry VIII. c. 19.

But the point in which theſe juriſdictions are the moſt defective, is that of enforcing their ſentences when pronounced; for which they have no other proceſs but that of *excommunication*; which would be often deſpiſed by obſtinate or profligate men, did not the civil law ſtep in with its aid. See EXCOMMUNICATION.

ECCLESIASTICAL Corporations, are where the members that compoſe them are *ſpiritual* perſons. They were erected for the furtherance of religion and perpetuating the rights of the church. See CORPORATIONS.

ECCLESIASTICAL State. See CLERGY.

ECCLESIASTICUS, an apocryphal book, generally bound up with the Scriptures; ſo called, from its being read in the church, *eccleſia*, as a book of piety and inſtruction, but not of infallible authority.

The author of this book was a Jew, called *Jeſus the ſon of Sirach*. The Greeks call it the *Wiſdom of the ſon of Sirach*.

ECCOPROTICS, in *Medicine*, laxative or looſening remedies, which purge gently, by ſoftening the humours and excrements, and fitting them for expulſion.—The word is compoſed of the Greek particle εκ, and κοπρος, *excrement*.

ECDICI, Εκδικοι, among the ancients, patrons of cities, who defended their rights, and took care of the public money. Their office reſembled that of the modern ſyndics.

ECHAPE, in the manege, a horſe begot between a ſtallion and a mare of different breeds and countries.

ECHAPER, in the manege, a galliciſm uſed in the academies, implying to give a horſe head, or to put on at full ſpeed.

ECHENEIS, the REMORA. See ICHTHYOLOGY *Index*.

ECHEVIN, in the French and Dutch polity, a magiſtrate elected by the inhabitants of a city or town, to take care of their common concerns, and the decoration and cleanlineſs of the city.

At Paris, there is a prevôt and four echevins; in other towns, a mayor and echevins. At Amſterdam, there are nine echevins; and at Rotterdam, ſeven.

In France, the echevins take cognizance of rents, taxes, and the navigation of rivers, &c. In Holland, they judge of civil and criminal cauſes; and if the criminal confeſſes himſelf guilty, they can ſee their ſentence executed without appeal.

ECHINATE, or ECHINATED, an appellation given to whatever is prickly, thereby reſembling the hedgehog.

ECHINITES, in *Natural Hiſtory*, the name by which authors call the foſſil centronia, frequently found in our chalk pits.

ECHINOPHORA. See BOTANY *Index*.

ECHINOPS. See BOTANY *Index*.

ECHINUS, a genus of animals belonging to the order of vermes molluſca. See HELMINTHOLOGY *Index*.

ECHINUS, in *Architecture*, a member or ornament near the bottom of the Ionic, Corinthian, and Compoſite capitals.

ECHITES. See BOTANY *Index*.

ECHIUM, VIPER'S BUGLOSS. See BOTANY *Index*.

ECHO, or ECCHO, a ſound reflected or reverberated, from a ſolid, concave, body, and ſo repeated to the ear *. The word is formed from the Greek ηχος, *ſound*, which comes from the verb ηχεω, *ſono*.

* See *Acouſtics*, N° 26.

The ancients being wholly unacquainted with the true cauſe of the echo, aſcribed it to ſeveral cauſes ſufficiently whimſical. The poets, who were not the worſt of their philoſophers, imagined it to be a perſon of that name metamorphoſed, and that ſhe affected to take up her abode in particular places; for they found by experience, that ſhe was not to be met with in all. (See below, ECHO in *fabulous hiſtory*.) But the moderns, who know ſound to conſiſt in a certain tremor or vibration in the ſonorous body communicated to the contiguous air, and by that means to the ear, give a more conſiſtent account of echo.

For a tremulous body, ſtriking on another ſolid body, it is evident, may be repelled without deſtroying or diminiſhing its tremor; and conſequently a ſound may be redoubled by the reſilition of the tremulous body, or air.

But a ſimple reflection of the ſonorous air is not enough to ſolve the echo: for then every plain ſurface of a ſolid hard body, as being fit to reflect a voice or ſound, would redouble it; which we find does not hold.

To produce an echo, therefore, it ſhould ſeem that a kind of concameration or vaulting were neceſſary, in order to collect, and by collecting to heighten and increaſe, and afterwards reflect, the ſound; as we find is the caſe in reflecting the rays of light, where a concave mirror is required.

In effect, as often as a ſound ſtrikes perpendicularly on a wall, behind which is any thing of a vault or arch, or even another parallel wall, ſo often will it be reverberated in the ſame line, or other adjacent ones.

For an echo to be heard, therefore, it is neceſſary the ear be in the line of reflection: for the perſon who made the ſound to hear its echo, it is neceſſary he be perpendicular to the place which reflects it: and for a manifold or tautological echo, it is neceſſary there be a number of walls, and vaults or cavities, either placed behind or fronting each other.

A ſingle arch or concavity, &c. can ſcarce ever ſtop and reflect all the ſound; but if there be a convenient diſpoſition behind it, part of the ſound propagated thither, being collected and reflected as before, will preſent another echo: or, if there be another concavity, oppoſed at a due diſtance to the former, the ſound reflected from the one upon the other will be toſſed back again by this latter, &c.

Many of the phenomena of echoes are well conſidered by the biſhop of Leighs, &c. who remarks, that any ſound, falling either directly or obliquely on any denſe body of a ſmooth, whether plain or arched, ſuperficies, is reflected, or echoes, more or leſs. The ſurface, ſays he, muſt be ſmooth; otherwiſe the air, by reverberation, will be put out of its regular motion, and the ſound thereby broken and extinguiſhed. He adds, that it echoes more or leſs, to ſhow, that when all things are as before deſcribed, there is ſtill an echoing, though it be not always heard, either becauſe the direct ſound is too weak to beat quite back again to him that made it; or that it does return to him, but ſo weak, that it cannot be diſcerned; or that he ſtands in a wrong place to receive the reflected ſound, which paſſes over his head, under his feet, or on one ſide of him; and which therefore may be heard by a man ſtanding in the place where the reflected ſound does come, provided no interpoſed body intercepts it, but not by him that firſt made it.

Echoes may be produced with different circumſtances. For, 1. A *plane* obſtacle reflects the ſound back in its due tone and loudneſs; allowance being made for the proportionable decreaſe of the ſound, according to its diſtance.

2. A *convex* obſtacle reflects the ſound ſomewhat ſmaller and ſomewhat quicker, though weaker, than otherwiſe it would be.

3. A *concàve* obſtacle echoes back the ſound, bigger, ſlower, and alſo inverted; but never according to the order of words.

Nor does it ſeem poſſible to contrive any ſingle echo, that ſhall invert the ſound, and repeat backwards; becauſe, in ſuch caſe, the word laſt ſpoken, that is, which laſt occurs to the obſtacle, muſt be repelled firſt; which cannot be. For where in the mean time ſhould the firſt words hang and be concealed; or how, after ſuch a pauſe, be revived, and animated again into motion?

From the determinate concavity or archedneſs of the reflecting bodies, it may happen that ſome of them ſhall only echo back one determinate note, and only from one place.

4. The echoing body being removed farther off, it reflects more of the ſound than when nearer; which is the reaſon why ſome echoes repeat but one ſyllable, ſome one word, and ſome many.

5. Echoing bodies may be ſo contrived and placed, as that reflecting the ſound from one to the other, either directly and mutually, or obliquely and by ſucceſſion, out of one ſound, a multiple echo or many echoes ſhall ariſe.

Add, that a multiple echo may be made, by ſo placing the echoing bodies at unequal diſtances, that they may reflect all one way, and not one on the other; by which means, a manifold ſucceſſive ſound will be heard; one clap of the hands, like many; one *ha*, like a laughter; one ſingle word, like many of the ſame tone and accent; and ſo one viol, like many of the ſame kind, imitating each other.

Laſtly, Echoing bodies may be ſo ordered, that from any one ſound given, they ſhall produce many echoes different both as to tone and intenſion. By which means a muſical room may be ſo contrived, that not only one inſtrument playing therein ſhall ſeem many of the ſame ſort and ſize, but even a concert of different ones, only by placing certain echoing bodies ſo, that any note played ſhall be returned by them in 3ds, 5ths, and 8ths.

ECHO, is alſo uſed for the place where the repetition of the ſound is produced or heard.

Echoes are diſtinguiſhed into divers kinds, viz.

1. *Single*, which return the voice but once. Whereof ſome are *tonical*, which only return a voice when modulated into ſome particular muſical tone: Others, *polyſyllabical*, which return many ſyllables, words, and ſentences. Of this laſt kind is that fine echo in Woodſtock park, which Dr Plot aſſures us, in the day time, will return very diſtinctly ſeventeen ſyllables, and in the night twenty.

2. *Multiple*, or *tautological;* which return ſyllables and words the ſame oftentimes repeated.

In echoes, the place where the ſpeaker ſtands is called the *centrum phonicum*, and the object or place that returns the voice, the *centrum phonocampticum*.

At the ſepulchre of Metella, wife of Craſſus, was an echo, which repeated what a man ſaid five times. Authors mention a tower at Cyzicus, where the echo repeated ſeven times. One of the fineſt echoes we read of is that mentioned by Barthius, in his notes on Statius's *Thebais*, lib. vi. 30. which repeated the words a man uttered 17 times: it was on the banks of the Naha, between Coblentz and Bingen. Barthius aſſures us, he had proved what he writes; and had told 17 repetitions. And whereas, in common echoes, the repetition is not heard till ſome time after hearing the word ſpoke, or the notes ſung; in this, the perſon who ſpeaks or ſings is ſcarce heard at all; but the repetition moſt clearly, and always in ſurpriſing varieties; the echo ſeeming ſometimes to approach nearer, and ſometimes to be further off. Sometimes the voice is heard very diſtinctly, and ſometimes ſcarce at all. One hears only one voice, and another ſeveral; one hears the echo on the right, and the other on the left, &c. At Milan in Italy, is an echo which reiterates the report of a piſtol 56 times; and if the report is very loud, upwards of 60 reiterations may be counted. The firſt 20 echoes are pretty diſtinct; but as the noiſe ſeems to fly away, and anſwer at a greater diſtance, the reiterations are ſo doubled, that they can ſcarce be counted. See an account of a remarkable echo under the article Paisley.

Echo, in *Architecture*, a term applied to certain kinds of vaults and arches, moſt commonly of the elliptic and parabolic figures, uſed to redouble ſounds, and produce artificial echoes.

Echo, in *Poetry*, a kind of compoſition wherein the laſt words or ſyllables of each verſe contain ſome meaning, which, being repeated apart, anſwers to ſome queſtion or other matter contained in the verſe; as in this beautiful one from Virgil:

> *Crudelis mater magis, an puer improbus ille?*
> *Improbus ille puer, crudelis tu quoque mater.*

The elegance of an echo conſiſts in giving a new ſenſe to the laſt words; which reverberate, as it were, the motions of the mind, and by that means affect it with ſurpriſe and admiration.

Echo, in fabulous hiſtory, a daughter of the Air and Tellus, who chiefly reſided in the vicinity of the Cephiſus. She was once one of Juno's attendants, and became the confidant of Jupiter's amours. Her loquacity, however, diſpleaſed Jupiter, and ſhe was deprived of the power of ſpeech by Juno, and only permitted to anſwer to the queſtions which were put to her. Pan had formerly been one of her admirers, but he never enjoyed her favours. Echo, after ſhe had been puniſhed by Juno, fell in love with Narciſſus; but being deſpiſed by him, pined herſelf to death, having nothing but her voice left.

ECHOMETER, among muſicians, a kind of ſcale or rule, with ſeveral lines thereon, ſerving to meaſure the duration and length of ſounds, and to find their intervals and ratios.

ECHOUERIES. See under Trichecus.

ECKIUS, John, an eminent and learned divine, profeſſor in the univerſity of Ingolſtadt, memorable for the oppoſition he gave to Luther, Melancthon, Caraloſtadius, and other leading Proteſtants in Germany. He wrote many polemical tracts; and among the reſt, a *Manual of Controverſies*, printed in 1535, in which he diſcourſes upon moſt of the heads conteſted between the Proteſtants and Papiſts. He was a man of uncommon learning, parts, and zeal, and died in 1543.

ECLECTICS (*eclectici*), a name given to ſome ancient philoſophers, who, without attaching themſelves to any particular ſect, took what they judged good and ſolid from each. Hence their denomination; which, in the original Greek, ſignifies, "that may be choſen," or "that chooſes;" of the verb εκλεγω, *I chooſe.*—Laertius notes, that they were alſo, for the ſame reaſon denominated *analogetici;* but that they call themſelves *Philalethes*, i. e. lovers of truth.

The chief or founder of the eclectici was one Potamon of Alexandria, who lived under Auguſtus and Tiberius; and who, weary of doubting of all things with the Sceptics and Pyrrhonians, formed the eclectic ſect; which Voſſius calls the *eclective.*

Towards the cloſe of the ſecond century, a ſect aroſe in the Chriſtian church under the denomination of *Eclectics*, or modern *Platonics*. They profeſſed to make truth the only object of their inquiry, and to be ready to adopt from all the different ſyſtems and ſects ſuch tenets as they thought agreeable to it.—However, they preferred Plato to the other philoſophers, and looked upon his opinions concerning God, the human ſoul, and things inviſible, as conformable to the ſpirit and genius of the Chriſtian doctrine. One of the principal patrons of this ſyſtem was Ammonius Saccas, who at this time laid the foundation of that ſect, afterwards diſtinguiſhed by the name of the new *Platonics*, in the Alexandrian ſchool. See Ammonius and Platonists.

Eclectics were alſo a certain ſet of phyſicians among the ancients, of whom Archigenes, under Trajan, was the chief, who ſelected from the opinions of all the other ſects that which appeared to them beſt and moſt rational; hence they are called *eclectics*, and their preſcriptions *medicina eclectica.*

ECLIPSE, in *Aſtronomy*, the deprivation of the light of the ſun, or of ſome heavenly body, by the interpoſition of another heavenly body between our ſight and it. See Astronomy *Index.*

ECLIPTA, in *Botany*, a genus of the polygamia ſuperflua order, belonging to the ſyngeneſia claſs of plants. The receptacle is chaffy; there is no pappus, and the corollulæ of the diſk quadrifid.

ECLIPTIC, in *Aſtronomy*, a great circle of the ſphere, ſuppoſed to be drawn through the middle of the zodiac, making an angle with the equinoctial of about

23° 30′, which is the ſun's greateſt declination; or, more ſtrictly ſpeaking, it is that path or way among the fixed ſtars, that the earth appears to deſcribe to an eye placed in the ſun. See ASTRONOMY *Index*.

Some call it *via Solis*, "the way of the ſun;" becauſe the ſun in his apparent annual motion never deviates from it, as all the other planets do more or leſs.

ECLIPTIC, in *Geography*, a great circle on the terreſtrial globe, not only anſwering to, but falling within, the plane of the celeſtial ecliptic. See GEOGRAPHY.

ECLOGUE, in *Poetry*, a kind of paſtoral compoſition, wherein ſhepherds are introduced converſing together. The word is formed from the Greek εκλογη *choice;* ſo that, according to the etymology, *eclogue* ſhould be no more than a ſelect or choice piece; but cuſtom has determined it to a farther ſignification, viz. a little elegant compoſition in a ſimple natural ſtyle and manner.

Idyllion and eclogue, in their primary intention, are the ſame thing: thus, the idyllia, ειδυλλια, of Theocritus, are pieces wrote perfectly in the ſame vein with the *eclogæ* of Virgil. But cuſtom has made a difference between them, and appropriated the name *eclogue* to pieces wherein ſhepherds are introduced ſpeaking: *idyllion*, to thoſe wrote like the eclogue, in a ſimple natural ſtyle, but without any ſhepherds in them.

ECLUSE, a ſmall but ſtrong town of the Dutch Low Countries, in the county of Flanders, with a good harbour and ſluices. The Engliſh beſieged it in vain in 1405, and the people of Bruges in 1436. But the Dutch, commanded by Count Maurice of Naſſau, took it in 1644. It is defended by ſeveral forts, and ſtands near the ſea. E. Long. 3. 10. N. Lat. 50. 25.

ECONOMY, POLITICAL. See *POLITICAL Economy*.

ECPHRACTICS, in *Medicine*, remedies which attenuate and remove obſtructions. See ATTENUANTS, and DEOBSTRUENTS, MATERIA MEDICA *Index*.

ECSTASY. See EXTASY.

ECSTATICI, Εκςατικοι, from εξιςημι, *I am entranced*, in antiquity, a kind of diviners who were caſt into trances or ecſtaſies, in which they lay like dead men, or aſleep, deprived of all ſenſe and motion; but, after ſome time, returning to themſelves, gave ſtrange relations of what they had ſeen or heard.

ECTHESIS, in church hiſtory, a confeſſion of faith, in the form of an edict, publiſhed in the year 639, by the emperor Heraclius, with a view to pacify the troubles occaſioned by the Eutychian hereſy in the eaſtern church. However, the ſame prince revoked it, on being informed that Pope Severinus had condemned it, as favouring the Monothelites; declaring at the ſame time, that Sergius, patriarch of Conſtantinople, was the author of it.

ECTHLIPSIS, among Latin grammarians, a figure of proſody, whereby the *m* at the end of a word, when the following word begins with a vowel, is elided, or cut off, together with the vowel preceding it, for the ſake of the meaſure of the verſe: thus they read *mult' ille*, for *multum ille*.

ECTROPIUM, in *Surgery*, is when the eyelids are inverted, or retracted, ſo that they ſhow their internal or red ſurface, and cannot ſufficiently cover the eye.

ECTYLOTICS, in *Pharmacy*, remedies proper for conſuming calloſities.

ECU, or ESCU, a French crown; for the value of which, ſee MONEY.

EDAY, one of the Orkney iſles, is about five miles and a half long, and about a mile and a half broad. It has ſeveral good harbours, and contains about 600 inhabitants.

EDDA, in antiquities, is a ſyſtem of the ancient Icelandic or Runic mythology, containing many curious particulars of the theology, philoſophy, and manners, of the northern nations of Europe; or of the Scandinavians, who had migrated from Aſia, and from whom our Saxon anceſtors were deſcended. Mr Mallet apprehends that it was originally compiled, ſoon after the Pagan religion was aboliſhed, as a courſe of poetical lectures, for the uſe of ſuch young Icelanders as devoted themſelves to the profeſſion of a *ſcald* or poet. It conſiſts of two principal parts; the *firſt* containing a brief ſyſtem of mythology, properly called the *Edda;* and the *ſecond* being a kind of art of poetry, and called *ſcalda* or *poetics*. The moſt ancient Edda was compiled by Soemund Sigfuſſon, ſurnamed the *Learned*, who was born in Iceland about the year 1057. This was abridged, and rendered more eaſy and intelligible about 120 years afterwards, by Snorro Sturleſon, who was ſupreme judge of Iceland in the years 1215 and 1222; and it was publiſhed in the form of a dialogue. He added alſo the ſecond part in the form of a dialogue, being a detail of different events tranſacted among the divinities. The only three pieces that are known to remain of the more ancient Edda of Soemund, are the Voluſpa, the Havamaal, and the Runic chapter. The Voluſpa, or prophecy of Vola or Fola, appears to be the text, on which the Edda is the comment. It contains, in two or three hundred lines, the whole ſyſtem of mythology diſcloſed in the Edda, and may be compared to the Sibylline verſes, on account of its laconic yet bold ſtyle, and its imagery and obſcurity. It is profeſſedly a revelation of the decrees of the Father of nature, and the actions and operations of the gods. It deſcribes the chaos, the formation of the world, with its various inhabitants, the function of the gods, their moſt ſignal adventures, their quarrels with Loke their great adverſary, and the vengeance that enſued; and concludes with a long deſcription of the final ſtate of the univerſe, its diſſolution and conflagration, the battle of the inferior deities and the evil beings, the renovation of the world, the happy lot of the good, and the puniſhment of the wicked. The Havamaal, or Sublime Diſcourſe, is attributed to the god Odin, who is ſuppoſed to have given theſe precepts of wiſdom to mankind; it is compriſed in about 120 ſtanzas, and reſembles the book of Proverbs. Mr Mallet has given ſeveral extracts of this treatiſe on the Scandinavian ethics. The Runic chapter contains a ſhort ſyſtem of ancient magic, and eſpecially of the enchantments wrought by the operation of Runic characters, of which Mr Mallet has alſo given a ſpecimen. A manuſcript copy of the Edda of Snorro is preſerved in the library of the univerſity of Upſal; the firſt part of which hath been publiſhed with a Swediſh and Latin verſion by M. Goranſon. The Latin verſion is printed as a ſupplement to M. Mallet's Northern Antiquities. The firſt edition of the Edda was publiſhed by Reſenius, profeſſor at Copenhagen, in a large quarto volume, in the year 1665; containing the text of the Edda, a Latin tranſlation by an Icelandic prieſt, a Daniſh verſion, and various readings from different MSS. M. Mallet has alſo given an Engliſh tranſlation of the firſt part, accompanied with remarks; from which we learn, that the Edda teaches the doctrine of the Supreme, called the *Univerſal Father*, and *Odin*, who lives for ever, governs all his kingdom, and directs the great things as well as the ſmall; who formed the heaven, earth, and air; made man, and gave him a ſpirit or ſoul, which ſhall live after the body ſhall have mouldered away; and then all the juſt ſhall dwell with him in a place *Gimle* or *Vingolf*, the palace of friendſhip; but wicked men ſhall go to Hela, or death, and from thence to Niflheim, or the abode of the wicked, which is below in the ninth world. It inculcates alſo the belief of ſeveral inferior gods and goddeſſes, the chief of whom is Frigga or Frea, i. e. *lady*, meaning hereby the earth, who was the ſpouſe of Odin or the Supreme God; whence we may infer that, according to the opinion of theſe ancient philoſophers, this Odin was the active principle or ſoul of the world, which uniting itſelf with matter, had thereby put it into a condition to produce the intelligences or inferior gods, and men and all other creatures. The Edda likewiſe teaches the exiſtence of an evil being called *Loke*, the calumniator of the gods, the artificer of fraud, who ſurpaſſes all other beings in cunning and perfidy. It teaches the creation of all things out of an abyſs or chaos; the final deſtruction of the world by fire; the abſorption of the inferior divinities, both good and bad, into the boſom of the grand divinity, from whom all things proceeded, as emanations of his eſſence, and who will ſurvive all things; and the renovation of the earth in an improved ſtate.

EDDISH, or EADISH, the latter paſture or graſs that comes after mowing or reaping; otherwiſe called *eagraſe* or *earſh*, and *etch*.

EDDOES, or EDDERS, in *Botany*, the American name of the ARUM *eſculentum*.

EDDY (Saxon), of *ed* "backward," and *ea* "water," among ſeamen, is where the water runs back contrary to the tide; or that which hinders the free paſſage of the ſtream, and ſo cauſes it to return again. That eddy water which falls back, as it were, on the rudder of a ſhip under ſail, the ſeamen call the *dead water*.

EDDY Wind is that which returns or is beat back from a ſail, mountain, or any thing that may hinder its paſſage.

EDELINCK, GERARD, a famous engraver, born at Antwerp, where he was inſtructed in drawing and engraving. He ſettled at Paris, in the reign of Louis XIV. who made him his engraver in ordinary. Edelinck was alſo counſellor in the Royal Academy of Painting. His works are particularly eſteemed for the neatneſs of the engraving, their brilliant caſt, and the prodigious eaſe apparent in the execution; and to this facility is owing the great number of plates we have of his; among which are excellent portraits of a great number of illuſtrious men of his time. Among the moſt admired of his prints, the following may be ſpecified as holding the chief place. 1. A battle between four horſemen, with three figures lying ſlain upon the ground, from Leonardo da Vinci. 2. A holy family, with Elizabeth, St John, and two angels, from the famous picture of Raphael in the king of France's collection. The firſt impreſſions are before the arms of M. Colbert were added at the bottom of the plate; the ſecond are with the arms; and in the third the arms are taken out, but the place where they had been inſerted is very perceptible. 3. Mary Magdalen bewailing her ſins, and trampling upon the riches of the world, from Le Brun. The firſt impreſſions are without the narrow border which ſurrounds the print. 4. Alexander entering into the tent of Darius, a large print on two plates, from Le Brun. This engraving belongs to the three battles, and triumphal entry of Alexander into Babylon, by Girard Audran, and completes the ſet. The firſt impreſſions have the name of *Goyton* the printer at the bottom. 5. Alexander entering into the tent of Darius (finiſhed by P. Drevet), from Peter Mignard. Edelinck died in 1707, in an advanced age, at the Hotel Royal at the Gobelins, where he had an apartment. He had a brother named *John*, who was a ſkilful engraver, but died young.

EDEN, (Moſes) the name of a country, with a garden, in which the progenitors of mankind were ſettled by God himſelf: The term denotes pleaſure or delight. It would be endleſs to recount the ſeveral opinions concerning its ſituation, ſome of them very wild and extravagant. Moſes ſays, that "a river went out of Eden to water the garden, and from thence it was parted and became into four heads." This river is ſuppoſed to be the common channel of the Euphrates and Tigris, after their confluence; which parted again, below the garden, into two different channels; ſo that the two channels before, and the other two after their confluence, conſtitute the heads mentioned by Moſes. Which will determine the ſituation of the garden to have been in the ſouth of Meſopotamia, or in Babylonia. The garden was alſo called *Paradiſe;* a term of Perſic original, denoting a garden. See PARADISE.

EDGINGS, in *Gardening*, the ſeries of ſmall but durable plants ſet round the edges or borders of flower beds, &c. The beſt and moſt durable of all plants for this uſe is box; which, if well planted and rightly managed, will continue in ſtrength and beauty for many years. The ſeaſons for planting this are the autumn, and very early in the ſpring: and the beſt ſpecies for this purpoſe is the dwarf Dutch box.

Formerly, it was alſo a very common practice to plant borders, or edgings, of aromatic herbs; as thyme, ſavory, hyſſop, lavender, and the like: but theſe are all apt to grow woody, and to be in part, or wholly, deſtroyed in hard winters. Daiſies, thrift, or ſea julyflower, and chamomile, are alſo uſed by ſome for this purpoſe: but they require yearly tranſplanting, and a great deal of trouble, elſe they grow out of form; and they are alſo ſubject to periſh in very hard ſeaſons.

EDHILING, EDHILINGUS, an ancient appellation of the nobility among the Anglo-Saxons.

The Saxon nation, ſays Nithard (Hiſt. lib. iv.) is divided into three orders or claſſes of people; the *edhilingi*, the *frilingi*, and the *lazzi;* which ſignify the nobility, the freemen, and the vaſſals or ſlaves.

Inſtead of *edhiling*, we ſometimes meet with *atheling*, or *ætheling*; which appellation was likewiſe given to the king's ſon, and the preſumptive heir of the crown. See ATHELING.

EDICT, in matters of polity, an order or inſtrument, ſigned and ſealed by a prince, to ſerve as a law to his ſubjects. We find frequent mention of the edicts of the prætor, the ordinances of that officer in the Roman law. In the French law, the edicts are of ſeveral kinds: ſome importing a new law or regulation; others, the erection of new offices; eſtabliſhments of duties, rents, &c.; and ſometimes articles of pacification. In France, edicts are much the ſame as a proclamation is with us: but with this difference, that the former have the authority of a law in themſelves, from the power which iſſues them forth; whereas the latter are only declarations of a law, to which they refer, and have no power in themſelves.

EDILE, or ÆDILE. See ÆDILE.

1 Origin of the name.

EDINBURGH, a city of Mid-Lothian in Scotland, ſituated in W. Long. 3°, and N. Lat. 56°, near the ſouthern bank of the river Forth.—The origin of the name, like that of moſt other cities, is very uncertain. Some imagine it to be derived from Eth, a ſuppoſed king of the Picts; others from Edwin, a Saxon prince of Northumberland, who overran the whole or greateſt part of the territories of the Picts about the year 617; while others chooſe to derive it from two Gaelic words *Dun Edin*, ſignifying the face of a hill. The name *Edinburgh* itſelf, however, ſeems to have been unknown in the time of the Romans. The moſt ancient title by which we find this city diſtinguiſhed is that of *Caſtelh Mynyd Agned;* which, in the Britiſh language, ſignifies "the fortreſs of the hill of St Agnes." Afterwards it was named *Caſtrum Puellarum*, becauſe the Pictiſh princeſſes were educated in the caſtle (a neceſſary protection in thoſe barbarous ages) till they were married.—The ages in which theſe names were given cannot indeed now be exactly aſcertained: but the town certainly cannot boaſt of very great antiquity; ſince, as Mr Whittaker informs us, the celebrated King Arthur fought a battle on the ſpot where it is ſituated towards the end of the fifth century.

2 Time of its foundation uncertain.

The Romans, during the time they held the dominion of part of this iſland, divided their poſſeſſions into ſix provinces. The moſt northerly of theſe was called *Valentia*, which comprehended all the ſpace between the walls of ADRIAN and SEVERUS. Thus, Edinburgh, lying on the very outſkirts of that province which was moſt expoſed to the ravages of the barbarians, became perpetually ſubject to wars and devaſtations; by means of which, the time of its firſt foundation cannot now be gueſſed at.

The caſtle is certainly very ancient. It continued in the hands of the Saxons or Engliſh from the invaſion of Octa and Ebuſa in the year 452 till the defeat of Egfrid king of Northumberland in 685 by the Picts, who then repoſſeſſed themſelves of it. The Saxon kings of Northumberland reconquered it in the ninth century; and it was retained by their ſucceſſors till the year 956, when it was given up to Indulphus king of Scotland. In 1093 it was unſucceſsfully beſieged by the uſurper Donald Bane. Whether the city was at that time founded or not is uncertain. Moſt probably it was: for as protection from violence was neceſſary in thoſe barbarous ages, the caſtle of Edinburgh could not fail of being an inducement to many people to ſettle in its neighbourhood; and thus the city would gradually be founded and increaſe.—In 1128, King David I. founded the abbey of Holyroodhouſe, for certain canons regular: and granted them a charter, in which he ſtyled the town *Burgo meo de Edwineſburgh*, "my borough of Edinburgh." By the ſame charter he granted theſe canons 40 ſhillings yearly out of the town revenues; and likewiſe 48 ſhillings more, from the ſame, in caſe of the failure of certain duties payable from the king's revenue; and likewiſe one half of the tallow, lard, and hides, of all the beaſts killed in Edinburgh.

3 Caſtle ſurrendered to the Engliſh.

In 1174, the caſtle of Edinburgh was ſurrendered to Henry II. of England, in order to purchaſe the liberty of King William I. who had been defeated and taken priſoner by the Engliſh. But when William recovered his liberty, he entered into an alliance with Henry, and married his couſin Ermengarde; upon which the caſtle was reſtored as part of the queen's dower.

In 1215, this city was firſt diſtinguiſhed by having a parliament and provincial ſynod held in it.—In 1296, the caſtle was beſieged and taken by Edward I. of England; but was recovered in 1313 by Randolph earl of Moray, who was afterwards regent of Scotland during the minority of King David II. At laſt King Robert deſtroyed this fortreſs, as well as all others in Scotland, leſt they ſhould afford ſhelter to the Engliſh in any of their after incurſions into Scotland.—It lay in ruins for a conſiderable number of years; but was afterwards rebuilt by Edward III. of England, who placed a ſtrong garriſon in it.

In 1341 it was reduced by the following ſtratagem. A man pretending to be an Engliſh merchant, came to the governor, and told him that he had on board his ſhip in the Forth ſome wine, beer, biſcuits, &c. which he would ſell him on very reaſonable terms. A bargain being made, he promiſed to deliver the goods next morning at a very reaſonable rate: but at the time appointed, twelve men, diſguiſed in the habit of ſailors, entered the caſtle with the goods and ſuppoſed merchant: and having inſtantly killed the porter and centinels, Sir William Douglas, on a preconcerted ſignal, ruſhed in with a band of armed men, and quickly made himſelf maſter of the place, after having cut moſt of the garriſon in pieces.

4 Cruel execution of the murderers of James I.

The year 1437 is remarkable for the execution of the earl of Athol and his accomplices, who had a concern in the murder of James I. The crime, it muſt be owned, was execrable; but the puniſhment was altogether ſhocking to humanity. For three days ſucceſſively the aſſaſſins were tortured by putting on their heads iron crowns heated red hot, diſlocating their joints, pinching their fleſh with red hot pinchers, and carrying them in that dreadful ſituation through the ſtreets upon hurdles. At laſt an end was put to their ſufferings, by cutting them up alive, and ſending the parts of their mangled bodies to the principal towns of the kingdom.

5 Edinburgh becomes the capital of Scotland.

About the end of the 14th century it was cuſtomary to conſider Edinburgh as the capital of the kingdom. The town of Leith, with its harbour and mills, had been beſtowed upon it by Robert I. in 1329; and his grandſon John earl of Carrick, who afterwards aſcended the throne by the name of Robert III. conferred upon all the burgeſſes the ſingular privilege of building

building houſes in the caſtle, upon the ſole condition that they ſhould be perſons of good fame; which we muſt undoubtedly conſider as a proof that the number of theſe burgeſſes was at that time very ſmall. In 1461, a very conſiderable privilege was conferred on the city by Henry VI. of England when in a ſtate of exile; viz. that its inhabitants ſhould have liberty to trade to all the Engliſh ports on the ſame terms with the city of London. This extraordinary privilege was beſtowed in conſequence of the kindneſs with which that king was treated in a viſit to the Scottiſh monarch at Edinburgh; but as Henry was never reſtored, his gratitude was not attended with any benefit to this city. From this time, however, its privileges continued to be increaſed from various cauſes. In 1482 the citizens had an opportunity of liberating King James from the oppreſſion of his nobles, by whom he had been impriſoned in the caſtle. On this account the provoſt was by that monarch made hereditary high ſheriff within the city, an office which he continues ſtill to enjoy. The council at the ſame time were inveſted with the power of making laws and ſtatutes for the government of the city; and the trades, as a teſtimony of the royal gratitude for their loyalty, received the banner known by the name of the *Blue Blanket;* an enſign formerly capable of producing great commotions, but which has not now been diſplayed for many years paſt. However, it ſtill exiſts; and the convener of the trades has the charge of keeping it.

6
Venereal diſeaſe imported.

It was not long after the diſcovery of America that the venereal diſeaſe, imported from that country, made its way to Edinburgh. As early as 1497, only five years after the voyage of Columbus we find it looked upon as a moſt dreadful plague; and the unhappy perſons affected with it were ſeparated as effectually as poſſible from ſociety. The place of their exile was Inchkeith, a ſmall iſland, near the middle of the Forth; which, ſmall as it is, has a ſpring of freſh water, and now affords paſture to ſome ſheep.

7
Origin of the town guard.

By the overthrow of James IV. at the battle of Flowden, the city of Edinburgh was overwhelmed with grief and confuſion, that monarch having been attended in his unfortunate expedition by the earl of Angus, then provoſt, with the reſt of the magiſtrates, and a number of the principal inhabitants, moſt of whom periſhed in the battle. After this diſaſter, the inhabitants being alarmed for the ſafety of their city, it was enacted that every fourth man ſhould keep watch at night; the fortifications of the town were renewed, the wall being alſo extended in ſuch a manner as to encloſe the Graſsmarket, and the field on which Heriot's Hoſpital, the Grey Friars Church, and Charity Workhouſe, ſtand. On the eaſt ſide it was made to encloſe the College, Infirmary, and High School; after which, turning to the north, it met the old wall at the Netherbow port. After this alarm was over, the inhabitants were gradually relieved from the trouble of watching at night, and a certain number of militia appointed to prevent diſturbances; who continue to this day, and are known by the name of the *Town Guard*. Before theſe new encloſures, moſt of the principal people lived in the Cowgate without the wall; and the burying place was ſituated where the Parliament Cloſe now is. In our days of peace, when no alarm of an enemy is at all probable, great part of the walls, with all the gates, have been taken down, and the city laid quite open, in order to afford more ready paſſage to the great concourſe of people with whom the ſtreet is daily filled. But at the period we ſpeak of, not only were the inhabitants much leſs numerous by reaſon of the ſmall extent of the city, but it was depopulated by a dreadful plague; ſo that, to ſtop if poſſible the progreſs of the infection, all houſes and ſhops were ſhut up for 14 days, and ſome where infected perſons had died were pulled down altogether.

8
Erection of wooden houſes.

In 1504, the tract of ground called the *Burrough Muir* was totally overgrown with wood, though now it affords not the ſmalleſt veſtige of having been in ſuch a ſtate. So great was the quantity at that time, however, that it was enacted by the town-council, that whoever inclined to purchaſe as much wood as was ſufficient to make a new front for their houſe, might extend it ſeven feet into the ſtreet. Thus the city was in a ſhort time filled with houſes of wood inſtead of ſtone; by which, beſides the inconvenience of having the ſtreet narrowed 14 feet, and the beauty of the whole entirely marred, it became much more liable to accidents by fire: but almoſt all theſe are now pulled down; and in doing this a ſingular taſte in the maſonry which ſupported them is ſaid to have been diſcovered.

9
Edinburgh deſtroyed by the Engliſh.

In 1542, a war with England having commenced through the treachery of Cardinal Beaton, an Engliſh fleet of 200 ſail entered the Forth; and having landed their forces, quickly made themſelves maſters of the towns of Leith and Edinburgh. They next attacked the caſtle, but were repulſed from it with loſs; and by this they were ſo enraged, that they not only deſtroyed the towns of Edinburgh and Leith, but laid waſte the country for a great way round.—Theſe towns, however, ſpeedily recovered from their ruinous ſtate; and, in 1547, Leith was again burned by the Engliſh after the battle of Pinkey, but Edinburgh was ſpared.

Several diſturbances happened in this capital at the time of the Reformation, of which an account is given under the article SCOTLAND; but none of theſe greatly affected the city till the year 1570, at which time there was a civil war on account of Q. Mary's forced reſignation. The regent, who was one of the contending parties, bought the caſtle from the perfidious governor (Balfour) for 5000l. and the priory of Pittenweem. He did not, however, long enjoy the fruits of this infamous bargain. Sir William Kirkaldy, the new governor, a man of great integrity and bravery, declared for the queen. The city in the mean time was ſometimes in the hands of one party and ſometimes of another; during which contentions, the inhabitants, as may eaſily be imagined, ſuffered extremely.

10
Siege of the caſtle in Queen Elizabeth's time.

In the year 1570 above mentioned, Queen Elizabeth ſent a body of 1000 foot and 300 horſe, under the command of Sir William Drury, to aſſiſt the king's party. The caſtle was ſummoned to ſurrender; and ſeveral ſkirmiſhes happened during the ſpace of two years, in which a kind of predatory war was carried on. At laſt a truce was agreed on till the month of January 1573; and this opportunity the earl of Morton, now regent, made uſe of to build two bulwarks acroſs the high ſtreet, nearly oppoſite to the tolbooth, to defend the city from the fire of the caſtle.

On the firſt of January, early in the morning, the governor began to cannonade the city. Some of the cannon were pointed againſt the fiſh-market, then held on the high ſtreet; and the bullets falling among the fiſhes, ſcattered them about in a ſurpriſing manner, and even drove them up ſo high in the air, that they fell down upon the tops of the houſes. This unuſual ſpectacle having brought a number of people out of their houſes, ſome of them were killed and others dangerouſly wounded. Some little time afterwards, ſeveral houſes were ſet on fire by ſhot from the caſtle, and burned to the ground; which greatly enraged the people againſt the governor. A treaty was at laſt concluded between the leaders of the oppoſite factions; but Kirkaldy refuſed to be comprehended in it. The regent therefore ſolicited the aſſiſtance of Queen Elizabeth, and Sir William Drury was again ſent into Scotland with 1500 foot and a train of artillery. The caſtle was now beſieged in form, and batteries raiſed againſt it in different places. The governor defended himſelf with great bravery for 33 days; but finding moſt of the fortifications demoliſhed, the well choked up with rubbiſh, and all ſupplies of water cut off, he was obliged to ſurrender. The Engliſh general, in the name of his miſtreſs, promiſed him honourable treatment; but the queen of England ſhamefully gave him up to the regent, by whom he was hanged.

11
The city incurs the diſpleaſure of James VI.

Soon after this, the ſpirit of fanaticiſm, which ſucceeded the Reformation, produced violent commotions, not only in Edinburgh, but through the whole kingdom. The foundation of theſe diſturbances, and indeed of moſt others which have ever happened in Chriſtendom on account of religion, was that pernicious maxim of Popery, that the church is independent of the ſtate. It is not to be ſuppoſed that this maxim was at all agreeable to the ſovereign; but ſuch was the attachment of the people to the doctrines of the clergy, that King James found himſelf obliged to compound matters with them. This, however, anſwered the purpoſe but very indifferently; and at laſt a violent uproar was excited. The king was then ſitting in the court of ſeſſion, which was held in the tolbooth, when a petition was preſented to him by ſix perſons, lamenting the dangers which threatened religion; and being treated with very little reſpect by one Bruce a miniſter, his majeſty aſked who they were that dared to convene againſt his proclamation? He was anſwered by Lord Lindſay, that they dared to do more, and would not ſuffer religion to be overthrown. On this the king perceiving a number of people crowding into the room, withdrew into another without making any reply, ordering the door to be ſhut. By this the petitioners were ſo much enraged, that on their return to the church the moſt furious reſolutions were taken; and had it not been for the activity of Sir Alexander Home the provoſt, and Mr Watt the deacon convener who aſſembled the crafts in his majeſty's behalf, it is more than probable that the door would have been forced, and an end put to his life. This affront was ſo much reſented by the king, that he thought proper to declare Edinburgh an unfit place of reſidence for the court or the adminiſtration of juſtice. In conſequence of this declaration, he commanded the college of juſtice, the inferior judges, and the nobility and barons, to retire from Edinburgh, and not to return without expreſs licenſe. This unexpected declaration threw the whole town into conſternation, and brought back the magiſtrates and principal inhabitants to a ſenſe of their duty. With the clergy it was far otherwiſe. They railed againſt the king in the moſt furious manner; and endeavouring to perſuade the people to take up arms, the magiſtrates were ordered to impriſon them: but they eſcaped by a timely flight. A deputation of the moſt reſpectable burgeſſes was then ſent to the king at Linlithgow, with a view to mitigate his reſentment. But he refuſed to be pacified; and on the laſt day of December 1596 entered the town between two rows of his ſoldiers who lined the ſtreets, while the citizens were commanded to keep within their houſes. A convention of the eſtates was held in the tolbooth, before whom the magiſtrates made the moſt abject ſubmiſſions, but in vain. The convention declared one of the late tumults, in which an attack had been made upon the king's perſon, to be high treaſon; and ordained, that if the magiſtrates did not find out the authors, the city itſelf ſhould be ſubjected to all the penalties due to that crime. It was even propoſed to raze the town to the foundation, and erect a pillar on the ſpot where it had ſtood, as a monument of its crimes. The inhabitants were now reduced to the utmoſt deſpair; but Queen Elizabeth interpoſing in behalf of the city, the king thought proper to abate ſomewhat of his rigour. A criminal proſecution, however, was commenced, and the town council were commanded to appear at Perth by the firſt of February. On their petition, the time for their appearance was prolonged to the firſt of March; and the attendance of 13 of the common council was declared ſufficient, provided they had a proper commiſſion from the reſt. The trial commenced on the 5th day of the month; and one of the number having failed in his attendance, the cauſe was immediately decided againſt the council; they were declared rebels, and their revenues forfeited.

12
Is again received into favour.

For 15 days the city continued in the utmoſt confuſion; but, at laſt, on their earneſt ſupplication, and offering to ſubmit entirely to the king's mercy, the community were reſtored on the following conditions, which they had formerly proffered: That they ſhould continue to make a moſt diligent ſearch for the authors of the tumult in order to bring them to condign puniſhment; that none of the ſeditious miniſters ſhould be allowed to return to their charges, and no others admitted without his majeſty's conſent; and that in the election of their magiſtrates they ſhould preſent a liſt of the candidates to the king and his lords of council and ſeſſion, whom his majeſty and their lordſhips might approve or reject at pleaſure. To theſe conditions the king now added ſome others; viz. that the houſes which had been poſſeſſed by the miniſters ſhould be delivered up to the king; and that the clergymen ſhould afterwards live diſperſed through the town, every one in his own pariſh: That the town council houſe ſhould be appointed for accommodating the court of exchequer: and that the town ſhould become bound for the ſafety of the lords of ſeſſion from any attempts of the burgeſſes, under a penalty of 40,000 merks; and, laſtly, that the town ſhould immediately pay 20,000 merks to his majeſty.

Upon theſe terms a reconciliation took place; which appears to have been very complete, as the king not only allowed the degraded miniſters to be replaced, but in 1610 conferred a mark of his favour on the town, by allowing the provoſt to have a ſword of ſtate carried before him, and the magiſtrates to wear gowns on public occaſions. In 1618 he paid his laſt viſit to this city; when he was received with the moſt extravagant pomp and magnificence. See SCOTLAND.

13 Proceedings of the magiſtrates, &c.

The events which, during this period, regard the internal police of the city, were principally the following. After the unfortunate battle at Pinkey, the magiſtrates, probably apprehending that now their power was enlarged by reaſon of the preſent calamity, proceeded in ſome reſpects in a very arbitrary manner; forcing the inhabitants to furniſh materials for the public works; enjoining merchants to bring home ſilver to be coined at the mint; and ordering lanterns to be hung out at proper places to burn till nine at night, &c. Another invaſion from England being apprehended in 1558, the city raiſed 1450 men for its defence, among whom there are ſaid to have been 200 tailors, ſo that their profeſſion ſeems to have been in a very flouriſhing ſtate at that time. During the diſturbances which happened at the Reformation, and of which a particular account is given under the article SCOTLAND, it was enacted, that the figure of St Giles ſhould be cut out of the town ſtandard, and that of a thiſtle inſerted in its place. It was likewiſe enacted, that none but thoſe who profeſſed the reformed religion ſhould ſerve in any office whatever; and the better to preſerve the extraordinary appearance of ſanctity which was affected, a pillar was erected in the North Loch, for the purpoſe of ducking fornicators.

In 1595, the boys of the High School roſe againſt their maſters; and ſuch was the barbariſm of thoſe days, that one of theſe ſtriplings ſhot a magiſtrate with a piſtol, who had come along with the reſt to reduce them to obedience. The reaſon of the uproar was, that they were in that year refuſed two vacations, which had been cuſtomary in former times: however, they were at laſt obliged to ſubmit, and ever ſince have been allowed one for about ſix weeks in the autumn. The ſame year the houſe of one of the bailies was aſſaulted by the tradeſmen's ſons, aſſiſted by journeymen who had not received the freedom of the town; he eſcaped with his life, but the offenders were baniſhed the city for ever.

14 Diſturbances in the time of Charles I.

In the beginning of the reign of Charles I. a perfect harmony ſeems to have ſubſiſted between the court and the city of Edinburgh; for in 1627 King Charles I. preſented the city with a new ſword and gown to be worn by the provoſt at the times appointed by his father James VI. Next year he paid a viſit to this capital, and was received by the magiſtrates in a moſt pompous manner; but ſoon after this the diſturbances aroſe which were not terminated but by the death of that unfortunate monarch. Theſe commenced on an attempt of Charles to introduce Epiſcopacy into the kingdom; and the firſt ſtep towards this was the erection of the three Lothians and part of Berwick into a dioceſe, Edinburgh being the epiſcopal ſeat, and the church of St Giles the cathedral. An account of the diſturbance occaſioned by the firſt attempt to read the prayer book there, is given under the article BRITAIN; but though the attempt was given over, the minds of the people were not to be quieted. Next winter they reſorted to town in ſuch multitudes, that the privy-council thought proper to publiſh two acts; by one of which the people were commanded, under ſevere penalties, to leave the town in 24 hours; and by the other, the court of ſeſſion was removed to Linlithgow. The populace and their leaders were ſo much enraged by the latter, that Lord Traquair and ſome of the biſhops narrowly eſcaped with their lives; and next year (1638) matters became ſtill more ſerious. For now, the king having provoked his ſubjects throughout all Scotland with the innovations he attempted in religion, Edinburgh was made the general place of rendezvous, and the moſt formidable aſſociations took place; an account of which has already been given under the article BRITAIN. Each of the towns in Scotland had a copy; and that which belonged to Edinburgh, crowded with 5000 names, is ſtill preſerved among the records of the city. Notwithſtanding this diſagreement, however, the king once more viſited Edinburgh in 1641, and was entertained by the magiſtrates at an expence of 12,000l. Scots. It does not appear that after this the city was in any way particularly concerned with the diſturbances which followed either throughout the remainder of the reign of Charles I. the commonwealth, or the reign of Charles II. In 1680 the duke of York with his ducheſs, the princeſs Anne, and the whole court of Scotland, were entertained by the city in the Parliament Houſe, at the expence of 15,000l. Scots. At this time it is ſaid that the ſcheme of building the bridge over the North Loch was firſt projected by the duke.

15 Regulations made by the magiſtrates.

From the time that King James VI. paid his laſt viſit to Edinburgh in 1618, till the time of the union in 1707, a conſiderable number of private regulations were made by the magiſtrates; ſome of them evidently calculated for the good of the city, others ſtrongly characteriſtic of that violent ſpirit of fanaticiſm which prevailed ſo much in the laſt century. Among the former was an act paſſed in 1621, that the houſes, inſtead of being covered with ſtraw or boards, ſhould have their roofs conſtructed of ſlate, tiles, or lead. This act was renewed in 1667; and in 1668 an act was paſſed regulating their height alſo. By this they were reſtrained to five ſtories, and the thickneſs of the wall determined to be three feet at bottom. In 1684 a lantern with a candle was ordered to be hung out on the firſt floor of every houſe, in order to light the ſtreets at night; and there were two coaches with four horſes each ordered to be bought for the uſe of the magiſtrates; but it does not appear how long they continued to be uſed. In 1681 the court of ſeſſion diſcontinued its ſittings in ſummer: but as this was found to be attended with inconvenience, an act was paſſed for their reſtoration, which has continued ever ſince. During the time of the civil war in 1649, the city was viſited by the plague, which is the laſt time that dreadful diſtemper hath made its appearance in this country. The infection was ſo violent, that the city was almoſt depopulated, the priſoners were diſcharged from the tolbooth, and an act was made for giving one Dr Joannes Politius a ſalary of 80l. Scots per month, for

viſiting

viſiting thoſe who were infected with the diſeaſe. In 1677 the firſt coffee houſes were allowed to be opened, but none without a licenſe: and the ſame year the town council regulated the price of penny weddings; ordaining the men to pay no more than two ſhillings, and the women 18 pence; very extravagant prices having been exacted before.

In contradiſtinction to theſe ſalutary acts, we may ſtate thoſe which ſhow an extravagant deſire of preſerving the appearance of virtue in the female ſex, as if it had been poſſible for others to inſpire them with virtuous notions if they had not imbibed them of themſelves. In 1633 an act of council was paſſed, by which women were forbidden to wear plaids over their faces, under penalty of five pounds and the forfeiture of the plaid for the firſt fault. Baniſhment was the puniſhment of the third. The reaſon aſſigned for this act was, that matrons were not known from ſtrumpets and looſe women, while the plaid continued to be worn over the face. This act was renewed in 1637 and 1638. Succeeding town councils continued to ſhow the ſame regard to theſe matters; for in 1695 they enacted, that no innkeeper, vintner, or aleſeller, ſhould for the future employ women as waiters or ſervants, under the penalty of five ſhillings ſterling for each.

The following anecdote may perhaps make the virtues of theſe legiſlators themſelves wear a ſuſpicious aſpect. In 1649 the city having borrowed 40,000l. Scots, in order to raiſe their quota of men for his majeſty, the payment of it was abſolutely refuſed by the town council when a demand was made for that purpoſe. That they might not, however, depend entirely upon their own opinion in a matter of ſuch importance, they took that of the General Aſſembly upon the ſubject; and it was determined by theſe reverend divines, that they were not in conſcience bound to pay for an unlawful engagement which their predeceſſors had entered into. But in 1652, Cromwell's parliament, who pretended to no leſs ſanctity than they, declared themſelves of a very different opinion; and on the application of one of the creditors, forced them to repay the ſum.

16
Infamous treatment of the marquis of Montroſe.

The treatment which the brave marquis of Montroſe met with, likewiſe fixes an indelible ſtigma both upon the magiſtrates and clergy at that time. Having been put under ſentence of excommunication, no perſon was allowed to ſpeak to him or do him the leaſt office of friendſhip. Being met without the city by the magiſtrates and town guard, he was by them conducted in a kind of gloomy proceſſion through the ſtreets bareheaded, and in an elevated cart made for the purpoſe; the other priſoners walking two and two before him. At the time of his execution he was attended by one of the miniſters, who according to his own account, did not chooſe to return till *he had ſeen him caſten over the ladder*.

17
Loyalty of the city in 1715 and 1725.

The union in 1707 had almoſt produced a war between the two kingdoms which it was deſigned to unite; and on that occaſion Edinburgh became a ſcene of the moſt violent diſturbances, of which a particular account is given under the article BRITAIN. During the time the act was paſſing, it was found abſolutely neceſſary for the guards and four regiments of foot to do duty in the city. The diſturbances were augmented by the diſagreement of the two members of parliament; and notwithſtanding the victory gained at that time by the court party, Sir Patrick Johnſton the provoſt, who voted for the union, was obliged afterwards to leave the country. In 1715 the city remained faithful to the royal cauſe, and proper meaſures were taken for its defence. A committee of ſafety was appointed, the city guard increaſed, and 400 men raiſed at the expence of the town. The trained bands likewiſe were ordered out, 100 of whom mounted guard every night: by which precautions the rebels were prevented from attempting the city: they however, made themſelves maſter of the citadel of Leith; but fearing an attack from the duke of Argyll, they abandoned it in the night time. A ſcheme was even laid for becoming maſters of the caſtle of Edinburgh; for which purpoſe they bribed a ſerjeant to place their ſcaling ladders. Thus ſome of the rebels got up to the top of the walls before any alarm was given; but in the mean time the plot being diſcovered by the ſerjeant's wife, her huſband was hanged over the place where he had attempted to introduce the rebels. The expence of the armament which the city had been at on this occaſion amounted to about 1700l. which was repaid by government in the year 1721.

18
Captain Porteous executed by a mob.

The loyalty of this city was ſtill farther remarkable in the year 1725, when diſturbances were excited in all parts of the kingdom, particularly in the city of Glaſgow, concerning the exciſe bill; for all remained quiet in Edinburgh, notwithſtanding the violent outcries that were made elſewhere; and ſo remarkable was the tranquillity in the metropolis, that government afterwards returned thanks to the magiſtrates for it. In 1736, however, the city had again the misfortune to fall under the royal diſpleaſure, on the following account. Two ſmugglers having been detected in ſtealing their own goods out of a cuſtomhouſe, were condemned to be hanged. The crime was looked upon as trivial; and therefore a general murmur prevailed among the populace, which was no doubt heightened by the following accident. At that time it had been cuſtomary for perſons condemned to die to be carried each Sunday to the church, called from that circumſtance the *Tolbooth church*. The two priſoners juſt mentioned were conducted in the uſual way, guarded by three ſoldiers, to prevent their making their eſcape: but having once gone thither a little before the congregation met, one of the priſoners ſeized one of the guards in each hand, and the other in his teeth, calling out to his companion to run; which he immediately did with ſuch ſpeed, that he ſoon got out of ſight, and was never heard of afterwards. The perſon who had thus procured the life of his companion without regard to his own, would no doubt become a general object of compaſſion; and of courſe, when led to the place of execution, the guard were ſeverely pelted by the mob, and ſome of them, according to the teſtimony of the witneſſes who were ſworn on the occaſion, pretty much wounded. By this Captain Porteous, who commanded the guard, was ſo much provoked, that he gave orders to fire, by which ſix people were killed and eleven wounded. The evidence, however, even of the fact that the orders to fire were given, appears not to have been altogether unexceptionable; nevertheleſs, on this he was tried and condemned to be executed. At that time the king was abſent in Hanover, having

having left the regency in the hands of the queen; and the caſe of the unfortunate Porteous having been repreſented to her, ſhe was pleaſed to grant him a reprieve: but ſuch was the inveteracy of the people againſt him, that they determined not to allow him to avail himſelf of the royal clemency. On the night previous to the day that had been appointed for his execution, therefore, a number of people aſſembled, ſhut the gates of the city, and burnt the door of the priſon, the ſame which the mob would formerly have broken open in order to murder King James. They then took out Porteous, whom it was found impoſſible to reſcue out of their hands, though every method that the magiſtrates could take for that purpoſe in ſuch a confuſion was made uſe of. It was even proved, that the member of parliament went to the commander in chief, and requeſted that he would ſend a party of ſoldiers to quell the diſturbance, but was abſolutely denied this requeſt, becauſe he could not produce a written order from the provoſt to this purport; which, in the confuſion then exiſting in the city, could neither have been expected to be given by the provoſt, nor would it have been ſafe for any perſon to have carried it about him. Thus the unhappy victim was left in the hands of his executioners; and being dragged by them to the place deſtined for receiving his fate, was hanged on a dyer's ſign poſt. As they had not brought a rope along with them, they broke open a ſhop where they knew they were to be had; and having taken out what they wanted, left the money upon the table, and retired without committing any other diſorder.

19 Government highly incenſed on that account.

Such an atrocious inſult on government could not but be highly reſented. A royal proclamation was iſſued, offering a pardon to any accomplice, and a reward of 200l. to any perſon who would diſcover one of thoſe concerned. The proclamation was ordered to be read from every pulpit in Scotland the firſt Sunday of every month for a twelvemonth: but ſo divided were the people in their opinions about this matter, that many of the clergy heſitated exceedingly about complying with the royal order, by which they were brought in danger of being turned out of their livings; while thoſe who complied were rendered ſo unpopular, that their ſituation was rendered ſtill worſe, than the others. All the efforts of government, however, were inſufficient to produce any diſcovery; by which, no doubt, the court were ſtill more exaſperated; and it was now determined to execute vengeance on the magiſtrates and city at large. Alexander Wilſon, the provoſt at that time, was impriſoned three weeks before he could be admitted to bail; after which, he and the four bailies, with the lords of juſticiary, were ordered to attend the houſe of peers at London. On their arrival there, a debate enſued, whether the lords ſhould attend in their robes or not? but at laſt it was agreed, that they ſhould attend in their robes at the bar. This however, was refuſed by their lordſhips, who inſiſted that they ſhould be examined within the bar; upon which the affair of their examination was dropped altogether. A bill at laſt paſſed both houſes, by which it was enacted, that the city of Edinburgh ſhould be fined in 2000l. for the benefit of Porteous's widow (though ſhe was prevailed upon to accept of 1500l. for the whole); and the provoſt was declared incapable of ever ſerving government again in any capacity whatever. To prevent ſuch cataſtrophes in time coming, the town council enacted, that, on the firſt appearance of an inſurrection, the chief officers in the different ſocieties and corporations ſhould repair to the council to receive the orders of the magiſtrates for the quelling of the tumult, under the penalty of 8l. 6s. 8d. for each omiſſion.

20 The city taken by the rebels in 1745.

In 1745, the city was inveſted by the Pretender's army; and on the 17th of September, the Netherbow gate being opened to let a coach paſs, a party of highlanders, who had reached the gate undiſcovered, ruſhed in, and took poſſeſſion of the city. The inhabitants were commanded to deliver up their arms at the palace or Holyroodhouſe; a certain quantity of military ſtores was required from the city, under pain of military execution; and an aſſeſſment of 2s. 6d. upon the pound was impoſed upon the *real* rents within the city and liberties for defraying that expence.

The Pretender's army guarded all the avenues to the caſtle; but no ſigns of hoſtilities enſued till the 25th of the month, when the garriſon being alarmed from ſome unknown cauſe, a number of cannon were diſcharged at the guard placed at the Weſt Port, but with very little effect. This gave occaſion to an order to the guard at the Weigh-houſe, to prevent all intercourſe between the city and caſtle; and then the governor acquainted the provoſt by letter, that unleſs the communication was preſerved, he would be obliged to diſlodge the guard by means of artillery. A deputation was next ſent to the Pretender; acquainting him with the danger the city was in, and entreating him to withdraw the guard. With this he refuſed to comply; and the highland centinels firing at ſome people who were carrying proviſions into the caſtle, a pretty ſmart cannonading enſued, which ſet on fire ſeveral houſes, killed ſome people, and did other damage. The Pretender then conſented to diſmiſs the guard, and the cannonading ceaſed. After the battle of Culloden, the provoſt of Edinburgh was obliged to ſtand a very long and ſevere trial, firſt at London and then at Edinburgh, for not defending the city againſt the rebels; which, from the ſituation and extent of the walls, every one muſt have ſeen to be impoſſible.

During this trial a very uncommon circumſtance happened; the jury having ſat two days, inſiſted that they could ſit no longer, and prayed for a ſhort reſpite. As the urgency of the caſe was apparent, and both parties agreed, the court, after long reaſoning adjourned till the day following, taking the jury bound under a penalty of 500l. each; when the court continued ſitting two days longer, and the jury were one day encloſed. The event was, that the provoſt was exculpated.

21 Government of the city reſtored.

After the battle of Culloden the duke of Cumberland cauſed fourteen of the rebel ſtandards to be burned at the croſs; that of the Pretender was carried by the common executioner, the others by chimney-ſweepers; the heralds proclaiming the names of the commanders to whom they belonged as they were thrown into the fire. At this time the city of Edinburgh felt a temporary inconvenience from the election of their magiſtrates not having taken place at the uſual time; ſo that it became neceſſary to apply to his majeſty for the reſtoration of the government of the city. This was readily granted, the burgeſſes being allowed a poll tax; after which an entire new ſet of magiſtrates was returned, all of them friends to the houſe of Hanover; and ſoon after the freedom of the city in a gold box was preſented to the duke of Cumberland.

With theſe tranſactions all interferences betwixt government and the metropolis of Scotland were ended; the reſt of its hiſtory therefore only conſiſts of internal occurrences, the regulations made by its own magiſtrates for the benefit of the city, their applications to government for leave to improve it, or the execution of theſe improvements; of which we ſhall now give a brief detail.

22
Salary beſtowed on the provoſt.

In the year 1716, the city firſt beſtowed a ſettled ſalary on the provoſt, in order to enable him to ſupport the dignity of the firſt magiſtrate. This was at firſt 300l; but has ſince been augmented to 500l. which his lordſhip ſtill enjoys. In 1718 it was recommended to the magiſtrates to diſtinguiſh themſelves by wearing coats of black velvet, for which they were allowed 10l. but this act being abrogated in 1754, gold chains were aſſigned as badges of their office, which they continue to wear. Provoſt Kincaid happened to die in office in the year 1777; which being a very rare accident, perhaps the only one of the kind to be met with in the records of Edinburgh, he was buried with great ſolemnity, and a vaſt concourſe of people attended.

23
Account of tumults.

Tumults have been frequent in Edinburgh, chiefly on account of the dearneſs of proviſions. In 1740 Bell's mills were firſt attacked by the populace, and afterwards Leith mills; nor could the rioters be diſperſed till the military had fired among them and wounded three, of whom one died; and it was found neceſſary to order ſome dragoons into the city in order to preſerve tranquillity. In 1742, another violent tumult took place, owing to a cuſtom of ſtealing dead bodies from their graves for anatomical purpoſes, which had then become common. The populace beat to arms, threatened deſtruction to the ſurgeons; and, in ſpite of the efforts of the magiſtrates, demoliſhed the houſe of the beadle at St Cuthbert's. In 1756 new diſturbances, which required the aſſiſtance of the military, took place: the cauſe at this time was the impreſſing of men for the war which was then commencing. A diſturbance was likewiſe excited in 1760. This was occaſioned by the footmen, who till then were allowed to follow their maſters into the playhouſe, and now took upon them to diſturb the entertainment of the company; the conſequence of which was, that they were turned out, and have ever ſince been obliged to wait for their maſters. In 1763 and 1765, the tumults on account of the price of proviſions were renewed; many of the mealmongers had their houſes broken open and their ſhops deſtroyed. The magiſtrates, as uſual, were obliged to call in a party of dragoons to quell the diſturbance; but at the ſame time, to put an effectual ſtop, as far as was in their power, to theſe proceedings for the future, they gave ſecurity, that people who brought grain or proviſion into the market ſhould be ſecured in their property. Since that time there have been no tumulrs directly on the account of proviſions; though in 1784 a terrible riot and attack of a diſtillery at Canonmills took place, on a ſuppoſition that the diſtillers enhanced the price of meal by uſing unmalted grain. The attack was repelled by the ſervants of the diſtillery; but the mob could not be quelled until the ſheriff called the ſoldiers quartered in the caſtle to his aſſiſtance. The ſame night a party of rioters ſet out for Ford, a place ten miles to the ſouthward, where there was likewiſe a large diſtillery; which, as there was none to make any oppoſition, they ſoon deſtroyed. One man was killed in this riot at Edinburgh by the fire of a ſervant of the diſtillery, and ſeveral of the rioters were afterwards ſecured and puniſhed.

In the years 1778 and 1779 two very alarming diſturbances happened, which threatened a great deal of bloodſhed, though happily they were terminated without any. The firſt was a mutiny of the earl of Seaforth's Highland regiment, who were at this time quartered in the caſtle. Theſe having been ordered to embark, for ſome reaſon or other unanimouſly refuſed, and poſted themſelves on the top of Arthur's ſeat, where they continued for two days. Troops were collected to prevent their eſcape, and the inhabitants were ordered to keep within doors at the firſt toll of the great bell, which was to be a ſignal of violence about to take place; but fortunately all the fears, naturally ariſing from the expectation of this event, were diſſipated by an accommodation. The other happened on account of the attempt to repeal the penal laws againſt the Papiſts; and was much more alarming than the other, as being the effect of a premeditated ſcheme and determined reſolution to oppoſe government. On the 2d of February 1779 a mob aſſembled in the evening, burned a Popiſh chapel, and plundered another. Next day they renewed their depredations; deſtroying and carrying off the books, furniture, &c. of ſeveral Popiſh prieſts and others of that perſuaſion. The riot continued all that day, though the aſſiſtance of the military was called in; but happily no lives were loſt, nor was there any firing. The city was afterwards obliged to make good the damage ſuſtained by the Catholics on this occaſion, which was eſtimated at 1500l. This year alſo an unlucky accident happened at Leith. About 50 Highland recruits having refuſed to embark, a party of the South Fencibles was ſent to take them priſoners. Unexpectedly, however, the Highlanders ſtood upon their defence; when, after ſome words, a firing commenced on both ſides, and about one half of the Highlanders were killed and wounded, the remainder being taken priſoners and carried to the caſtle. Captain Mansfield and two or three privates were killed in this affray.

24
General hiſtory of the improvements.

We ſhall cloſe this hiſtory of Edinburgh with a general account of the improvements which have lately taken place in it, and of which a particular deſcription will afterwards be given. Theſe began in the year 1753, when the foundation-ſtone of the Exchange was laid, at which time there was a grand proceſſion, and the greateſt concourſe of people ever known in Edinburgh. A triumphal arch was erected for the purpoſe, through which the proceſſion paſſed, and medals were ſcattered among the populace. In 1756 the high ſtreet was cleared by the removal of the croſs; though many regretted this, on account of its being a very ancient and elegant building. In the middle it had an unicorn placed on the top of a pillar 20 feet high; but this fine ornament was broken to pieces by the giving way of the tackle by which it was attempted to remove it. It is now again erected at Drum, a ſeat formerly belonging to Lord Somerville, about four miles

miles from Edinburgh. In 1763 the firſt ſtone of the North bridge was laid by Provoſt Drummond; and in 1767 an act of parliament was obtained for extending the royalty of the city over the fields to the northward, where the New Town is now ſituated. About the ſame time a ſpot of ground upon the ſouth ſide of the town was purchaſed by a private perſon for 1200l. which being feued out for building, gave riſe to the increaſe of the town on that quarter; and this proceeded the more rapidly, as the houſes built there were free from the dues impoſed upon others ſubject to the royalty. In 1774 the foundation of the Regiſter Office was laid. In 1784 the project for rendering the acceſs to the town equally eaſy on both ſides was begun to be put in execution by laying the foundation of the South bridge. At the ſame time a great improvement was made by reducing the height of the ſtreet ſeveral feet all the way from the place where the croſs ſtood to the Netherbow; by which means the aſcent is rendered more eaſy, not only for carriages, but alſo for perſons who walk on foot. At the ſame time, the ſtreet was farther cleared by the removal of the town guard houſe, which had long been complained of as an encumbrance. Within theſe three years (1805) part of the Luckenbooths has been removed, and it is ſtill farther in contemplation to remove the whole with the priſon. When this is accompliſhed, with other improvements by which it muſt neceſſarily be accompanied, it is to be queſtioned whether any city in Britain will be able to vie with Edinburgh in elegance and beauty.

Having thus given a conciſe hiſtory of the city from its earlieſt foundation, we ſhall now proceed to deſcribe it in its moſt improved ſtate.

25
Deſcription of Edinburgh.

Edinburgh is ſituated upon a ſteep hill, riſing from eaſt to weſt, and terminating in a high and inacceſſible rock, upon which the caſtle ſtands. At the eaſt end or lower extremity of this hill ſtands the abbey of Holyroodhouſe, or king's palace, diſtant from the caſtle upwards of a mile; and betwixt which, along the top of the ridge, and almoſt in a ſtraight line, runs the high ſtreet. On each ſide, and parallel to this ridge or hill, is another ridge of ground lower than that in the middle, and which does not extend ſo far to the eaſt; that on the ſouth being intercepted by Saliſbury rocks and Arthur's ſeat, a hill of about 800 feet of perpendicular height; and that on the north by the Calton hill, conſiderably lower than Arthur's ſeat: ſo that the ſituation of this city is moſt ſingular and romantic; the eaſt or lower part of the town lying between two hills; and the weſt or higher part riſing up towards a third hill, little inferior in height to the higheſt of the other two, upon which, as has been obſerved, the caſtle is built, and overlooks the town.

The buildings of the town terminate at the diſtance of about 200 yards from the caſtle gate; which ſpace affords a moſt delightful as well as convenient and healthful walk to the inhabitants. The proſpect from this ſpot is perhaps the fineſt anywhere to be met with, for extent, beauty, and variety.

In the valley or hollow betwixt the mid and the ſouth ridges, and nearly parallel to the high ſtreet, is another ſtreet called the Cowgate; and the town has now extended itſelf over moſt part of that ſouth ridge alſo. Betwixt the mid and the north ridges was a loch, which, till of very late, terminated the town on that ſide. From the high ſtreet towards the loch on the north, and Cowgate on the ſouth, run narrow croſs ſtreets or lanes, called *wynds* and *cloſes*, which grow ſteeper and ſteeper the farther weſt or nearer the caſtle; ſo that, were it not for the cloſeneſs and great height of the buildings, this city, from its ſituation and plan, might naturally be expected to be the beſt aired, as well as the cleaneſt, in Europe. The former, notwithſtanding theſe diſadvantages, it enjoys in an eminent degree; but we cannot compliment it upon the latter, notwithſtanding every poſſible means has been uſed by the magiſtrates for that purpoſe.

The ſteepneſs of the aſcent makes the acceſs to the high ſtreet from the north and ſouth very difficult; which no doubt greatly retarded the enlargement of the city. To remedy this inconvenience on the north, and with a view to extend the town on that quarter, a moſt elegant bridge has been thrown over the North Loch, which joins the north ridge to the middle of the high ſtreet, by ſo eaſy an aſcent as one in ſixteen; and in purſuance of the deſign, a plan of a new town to the north was fixed upon, and is now nearly finiſhed, with an elegance and taſte that does honour to this country. In like manner, to facilitate the acceſs from the ſouth ſide, a bridge has been thrown over the valley through which the Cowgate runs; which, if not equally elegant with the North bridge, is certainly as convenient.

26
Account of the gradual increaſe of Edinburgh.

The gradual increaſe of the city of Edinburgh may in ſome degree be underſtood from the traces of its ancient walls that ſtill remain. James II. in 1450, firſt beſtowed on the community the privilege of fortifying the city with a wall, and empowered them to levy a tax upon the inhabitants for defraying the expence. When the city was firſt fortified, the wall reached no further than the preſent water-houſe, or reſervoir, on the caſtle hill: from thence to the foot of Halkerſton's wynd, juſt below the new bridge, the city was defended by the North Loch; an inconſiderable moraſs, which, being formerly overflowed, formed a ſmall lake that hath ſince been drained. From this place to the foot of Leith wynd, it does not appear how the city was fortified? but from the foot of Leith wynd to the Nether-bow port it was defended only by a range of houſes; and when theſe had became ruinous, a wall was built in their place. The original wall of Edinburgh, therefore, began at the foot of the north-eaſt rock of the caſtle. Here it was ſtrengthened by a ſmall fortreſs, the ruins of which are ſtill to be ſeen, and are called the *Well-houſe Tower*, from their having a ſpring in their neighbourhood. When the wall came oppoſite to the reſervoir, it was carried quite acroſs the hill, having a gate on the top for making a communication between the town and caſtle. In going down the hill, it went ſlanting in an oblique direction to the firſt angle in going down the Weſt-bow, where was a gate named the *Upper-bow Port*, one of the hooks of which ſtill remains. Thence it proceeded eaſtward in ſuch a manner, as would have cut off not only all the Cowgate, but ſome part of the parliament houſe; and being continued as far as the Mint cloſe, it turned to the north-eaſt, and connected itſelf with the buildings on the north

north ſide of the high ſtreet, where was the original *Nether-bow Port*, about 50 yards weſt from that which afterwards went by the ſame name.

Soon after the building of this wall, a new ſtreet was formed on the outſide of it, named the *Cowgate*, which in the 16th century became the reſidence of the nobility, the ſenators of the college of juſtice, and other perſons of the firſt diſtinction. After the fatal battle of Flowden, however, the inhabitants of the Cowgate became very anxious to have themſelves defended by a wall as well as the reſt. The wall of the city was therefore extended to its preſent limits. This new wall begins on the ſouth-eaſt ſide of the rock on which the caſtle is built, and to which the town wall comes quite cloſe. From thence it deſcends obliquely to the Weſt Port; then aſcends part of a hill on the other ſide, called the *High Riggs;* after which, it runs eaſtward with but little alteration in its courſe, to the Briſto and Potter-row ports, and from thence to the Pleaſance. Here it takes a northerly direction, which it keeps from thence to the Cowgate port; after which the encloſure is completed to the Nether-bow by the houſes of St Mary's wynd. The original Nether-bow port being found not well adapted for defence was pulled down, and a new one built in 1571 by the adherents of Queen Mary. In 1606, the late handſome building was erected about 50 yards below the place where the former ſtood. It was two ſtories high, and had an elegant ſpire in the middle; but being thought to encumber the ſtreet, and the whole building being in a crazy ſituation, it was pulled down by order of the magiſtrates in 1764.

In the original wall of Edinburgh there was, as has been already obſerved, a port on the Caſtle hill. On the extenſion of the wall, after building the houſes in the Cowgate, this gate was pulled down. That in the upper or Weſt-bow ſtood for a much longer time, and was pulled down within the memory of ſome perſons lately or perhaps ſtill living. Beſides theſe, there was a third, about 50 yards above the head of the Canongate; but whether there were any more, is uncertain. The ports or gates of the new walls were, 1. The *Weſt Port*, ſituated at the extremity of the Graſs Market; beyond which lies a ſuburb of the town and a borough of regality, called *Portſburgh*. Next to this is a wicket, ſtruck out of the town wall in 1744, for the purpoſe of making an eaſier communication between the town and the public walks in the meadows, than by Briſto port. The next to this was *Briſto Port*, built in 1515; beyond which lies a ſuburb called *Briſto Street*. At a ſmall diſtance from Briſto was the *Potter-row Port*, which took this name from a manufactory of earthen ware in the neighbourhood. Formerly it was called *Kirk of Field Port*. Between this and the Cowgate port ſtood another, called *St Mary's Wynd Port*, which extended from eaſt to weſt acroſs the foot of the Pleaſance, and which was demoliſhed only ſince the middle of the laſt century. Cloſe to the middle of this ſtood the *Cowgate Port;* which opened a communication between the Cowgate and St Mary's wynd, and the Pleaſance. The *Nether-bow Port* has been already ſpoken of. At the foot of Leith wynd was another gate, known by the name of *Leith Wynd Port;* and within it was a wicket giving acceſs to the church of Trinity College, and which ſtill remains. At the foot of Halkerſton's wynd was another, which, as well as the former, was built about the year 1560. Both of theſe were pulled down ſome years ago, and all the reſt in 1785. Another ſtill remains at the foot of the Canongate, known by the name of the *Water-gate*.

For 250 years the city of Edinburgh occupied the ſame ſpace of ground, and it is but very lately that its limits have been ſo conſiderably enlarged. In the middle of the 16th century, it is deſcribed as extending in length about an Italian mile, and about half as much in breadth; which anſwers very nearly to its preſent limits, the late enlargements only excepted. This ſpace of ground, however, was not at that time occupied in the manner it is at preſent. The houſes were neither ſo high nor ſo crowded upon each other as they are now. This was a conſequence of the number of inhabitants increaſing, which has occaſioned the raiſing of the houſes to ſuch a height as is perhaps not to be paralleled in any other part of the world. Till the time of the Reformation, the burying ground of the city extended over all the ſpace occupied by the Parliament ſquare, and from thence to the Cowgate. The lands lying to the ſouthward of the Cowgate were chiefly laid out in gardens belonging to the convent of Black friars, and the church of St Mary in the Field. Theſe extended almoſt from the Pleaſance to the Potterrow port. From the Briſto to the Weſt port the ground was laid out in gardens belonging to the Gray friars. The magiſtrates, on their application to Queen Mary, obtained a grant of the Gray friars gardens for a burying place; for which it was given as a reaſon, that they were ſomewhat diſtant from the town. Here, however, it muſt be underſtood, that theſe gardens were diſtant from the houſes, and not without the walls; for they had been incloſed by them long before. In the time of James I. the houſes within the walls ſeem to have been in general, if not univerſally, covered with thatch or broom; and not above 20 feet high. Even in the year 1621, theſe roofs were ſo common, that they were prohibited by act of parliament, in order to prevent accidents from fire. In the middle of the laſt century, there were neither courts nor ſquares in Edinburgh. The Parliament cloſe or ſquare is the oldeſt of this kind in the city. Miln's ſquare, James's court, &c. were built long after; and Argyll's and Brown's ſquares about the years 1750 or 1760.

27 New Town. The *New Town* was projected in the year 1752; but as the magiſtrates could not then procure an extenſion of the royalty, the execution of the deſign was ſuſpended for ſome time. In 1767, an act was obtained, by which the royalty was extended over the fields to the northward of the city; upon which advertiſements were publiſhed by the magiſtrates, deſiring proper plans to be given in. Plans were given in accordingly, and that deſigned by Mr James Craig architect was adopted. Immediately afterwards, people were invited to purchaſe lots from the town council; and ſuch as purchaſed became bound to conform to the rules of the plan. In the mean time, however, the town council had ſecretly reſerved to themſelves a privilege of departing from their own plan; which they afterwards made uſe of in ſuch a manner as produced a law ſuit. According to the plan held forth to the purchaſers, a canal was to be made through that place

place where the North Loch had been, and the bank on the north ſide of it laid out in terraces: but inſtead of this, by an act of council, liberty was reſerved to the town to build upon this ſpot; and therefore, when many gentlemen had built genteel houſes in the new town on faith of the plan, they were ſurpriſed to find the ſpot appointed for terraces and a canal, beginning to be covered with mean irregular buildings, and work houſes for tradeſmen. This deviation was immediately complained of; but as the magiſtrates ſhowed no inclination to grant any redreſs, a proſecution was commenced againſt them before the Lords of Seſſion. In that court the cauſe was given againſt the purſuers, who thereupon appealed to the Houſe of Lords. Here the ſentence of the Court of Seſſion was reverſed, and the cauſe remitted to the conſideration of their Lordſhips. At laſt, after an expenſive conteſt, matters were accommodated. The principal term of accommodation was, that ſome part of the ground was to be laid out in terraces and a canal; but the time of diſpoſing it in that manner, was referred to the Lord Preſident of the Court of Seſſion and the Lord Chief Baron of the Exchequer. The fall of part of the bridge, hereafter mentioned, proved a very conſiderable diſadvantage to the New Town; as it neceſſarily induced a ſuſpicion that the paſſage, by means of the bridge, could never be rendered ſafe. An overſight of the magiſtrates proved of more eſſential detriment. A piece of ground lay to the ſouthward of the Old Town, in a ſituation very proper for building. This the magiſtrates had an opportunity of purchaſing for 1200l; which, however, they neglected, and it was bought by a private perſon, who immediately feued it out in lots for building, as has been already mentioned. The magiſtrates then began to ſee the conſequence, namely, that this ſpot being free from the duties to which the royalty of Edinburgh is ſubject, people would chooſe to reſide there rather than in the New Town. Upon this they offered the purchaſer 2000l. for the ground for which he had paid 1200l.; but as he demanded 20,000l. the bargain did not take place. Notwithſtanding theſe diſcouragements, the New Town is now almoſt finiſhed; and from the advantages of its ſituation, and its being built according to a regular plan, it hath undoubtedly a ſuperiority over any city in Britain. By its ſituation, however, it is remarkably expoſed to ſtorms of wind, which, at Edinburgh, ſometimes rage with uncommon violence.

It has three ſtreets, almoſt a mile in length, running from eaſt to weſt, interſected with croſs ſtreets at proper diſtances. The moſt northerly, called *Queen's Street*, till lately that Heriot row was built, is 100 feet broad, and commands an extenſive proſpect of the Forth, the county of Fife, and the ſhipping in the river. That called *George's Street*, which is in the middle, is no leſs than 115 feet wide. It is terminated at each end by two very elegant and extenſive ſquares; that on the eaſt end is called *St Andrew's Square;* the other, which is not yet finiſhed, is called *Charlotte's Square*. Prince's ſtreet is the moſt ſoutherly; and extends from the northern extremity of the bridge, quite to the weſt end of the town. It has only been finiſhed this year (1805). From the weſt end of Prince's ſtreet, a ſpacious road has been lately opened to join the two roads to Glaſgow by Airdrie and Whitburn. This has greatly improved the approach to the town from the weſt.

The moſt remarkable public buildings in Edinburgh are—

28
Public buildings deſcribed.

1. *The Caſtle.* This ſtands on a high rock, acceſſible only on the eaſt ſide. On all others it is very ſteep, and in ſome places perpendicular. It is about 300 feet high from its baſe: ſo that, before the invention of artillery, it might well have been deemed impregnable; though the event ſhowed that it was not. The entry to this fortreſs is defended by an outer barrier of palliſadoes; within this is a dry ditch, draw-bridge, and gate, defended by two batteries which flank it; and the whole is commanded by a half-moon mounted with braſs cannon, carrying balls of 12 pounds. Beyond theſe are two gate-ways, the firſt of which is very ſtrong, and has two portculiſſes. Immediately beyond the ſecond gate way, on the right hand, is a battery mounted with braſs cannon, carrying balls of 12 and 18 pounds weight. On the north ſide are a mortar and ſome gun batteries. The upper part of the caſtle contains a half-moon battery, a chapel, a parade for exerciſe, and a number of houſes in the form of a ſquare, which are laid out in barracks for the officers. Beſides theſe there are other barracks ſufficient to contain 1000 men; a powder magazine, bomb proof; a grand arſenal, capable of containing 8000 ſtand of arms; and other apartments for the ſame uſe, which can contain 22,000 more: ſo that 30,000 ſtand of arms may be conveniently lodged in this caſtle. On the eaſt ſide of the ſquare above mentioned, were formerly royal apartments; in one of which King James VI. was born, and which is ſtill ſhown to thoſe who viſit the caſtle. In another, the regalia of Scotland were depoſited on the 26th of March 1707; but as they were never ſhown to any body, a ſuſpicion has ariſen that they were carried to London, perhaps during the rebellions 1715 or 1745. This apartment was opened in 1794 by an order from government, in preſence of the firſt civil officers of the crown, as the lord preſident of the court of ſeſſion, the lord juſtice clerk, &c. but no part of the regalia was found.

The governor of the caſtle is generally a nobleman, whoſe place is worth about 1000l. a-year; and that of deputy governor, 500l. This laſt reſides in the houſe appointed for the governor, as the latter never inhabits it. There is alſo a fort-major, a ſtore-keeper, maſter gunner, and chaplain; but as this laſt does not reſide in the caſtle, worſhip is ſeldom performed in the chapel. The parliament houſe was formerly included in the great ſquare on the top, and the royal gardens were in the marſh afterwards called the *North Loch;* the king's ſtables being on the ſouth ſide, where the houſes ſtill retain the name, and the place where the barns were ſtill retain the name of Caſtlebarns.

The caſtle is defended by a company of invalids, and four or five hundred men belonging to ſome marching regiment, though it can accommodate 1000, as above mentioned; and this number has been ſometimes kept in it. Its natural ſtrength of ſituation was not ſufficient to render it impregnable, even before the invention of artillery, as we have already obſerved; much leſs would it be capable of ſecuring it againſt the attacks of a modern army well provided with cannon. It could not, in all

all probability, withſtand, even for a few hours, a well-directed bombardment: for no part but the powder magazine is capable of reſiſting theſe deſtructive machines; and the ſplinters from the rock on which the caſtle is built, could not fail to render them ſtill more formidable. Beſides, the water of the well, which is very bad, and drawn up from a depth of 100 feet, is apt to ſubſide on the continued diſcharge of artillery, which produces a concuſſion in the rock.

2. *The Palace of Holyroodhouſe.* This, though much neglected, is the only royal habitation in Scotland that is not entirely in ruins. It is a handſome ſquare of 230 feet in the inſide, ſurrounded with piazzas. The front, facing the weſt, conſiſts of two double towers joined by a beautiful low building, adorned with a double baluſtrade above. The gate-way in the middle is decorated with double ſtone columns, ſupporting a cupola in the middle, repreſenting an imperial crown, with a clock underneath. On the right hand is the great ſtaircaſe which leads to the council chamber and the royal apartments. Theſe are large and ſpacious, but unfurniſhed: in one of them the Scotch peers meet to elect 16 of their number to repreſent them in parliament. The gallery is on the left hand, and meaſures 150 feet by 27½. It is adorned with the ſuppoſed portraits of all the kings of Scotland. In the apartments of the duke of Hamilton, which he poſſeſſes as hereditary keeper of the palace, Queen Mary's bed of crimſon damaſk, bordered with green fringes and taſſels, is ſtill to be ſeen, but almoſt reduced to rags. Here alſo ſtrangers are ſhown a piece of wainſcot hung upon hinges, which opens to a trap ſtair communicating with the apartments below. Through this paſſage Darnley and the other conſpirators ruſhed in to murder the unhappy Rizzio. Towards the outward door of theſe apartments are large duſky ſpots on the floor, ſaid to be occaſioned by Rizzio's blood, which could never be waſhed out. In the lodgings aſſigned to Lord Dunmore is a picture by Van Dyke, eſteemed a maſterly performance, of King Charles I. and his queen going a-hunting. There are likewiſe the portraits of their preſent majeſties at full length by Ramſay. The lodgings above the royal apartments are occupied by the duke of Argyll as heritable maſter of the houſehold.

The front of this palace is two ſtories high; the roof flat; but at each end the front projects, and is ornamented with circular towers at the angles. Here the building is much higher, and the reſt of the palace is three ſtories in height. The north-weſt towers were built by James V. for his own reſidence: his name is ſtill to be ſeen below a niche in one of theſe towers. During the minority of Queen Mary, this palace was burned by the Engliſh; but ſoon after repaired and enlarged beyond its preſent ſize. At that time it conſiſted of five courts, the moſt weſterly of which was the largeſt. It was bounded on the eaſt by the front of the palace, which occupied the ſame ſpace it does at preſent; but the building itſelf extended further to the ſouth. At the north-weſt corner was a ſtrong gate with Gothic pillars, arches, and towers, part of which was not long ago pulled down. Great part of the palace was burnt by Cromwell's ſoldiers; but it was repaired and altered into the preſent form after the Reſtoration. The fabric was planned by Sir William Bruce a celebrated architect, and executed by Robert Mylne maſon. The environs of the palace afford an aſylum for inſolvent debtors; and adjoining to it is an extenſive park, all of which is a ſanctuary.

The abbey church was formerly called the *monaſtery of Holyroodhouſe*, and built by King David I. in 1128. He gave it the name of *Holyroodhouſe*, in memory, as is ſaid of his deliverance from an enraged hart, by the miraculous interpoſition of a croſs from heaven. This monaſtery he gave to the canons regular of St Auguſtine: on whom he alſo beſtowed the church of Edinburgh caſtle, with thoſe of St Cuthbert's, Corſtorphin, and Libberton, in the ſhire of Mid Lothian, and of Airth in Stirlingſhire; the priories of St Mary's Iſle in Galloway, of Blantyre in Clydeſdale, of Rowadill in Roſs, and three others in the Weſtern Iſles. To them he alſo granted the privilege of erecting a borough between the town of Edinburgh and the church of Holyroodhouſe. From theſe canons it had the name of the *Canongate*, which it ſtill retains. In this new borough they had a right to hold markets. They had alſo portions of land in different parts, with a moſt extenſive juriſdiction, and right of trial by duel, and fire and water ordeal. They had alſo certain revenues payable out of the exchequer and other funds, with fiſhings, and the privilege of erecting mills on the water of Leith, which ſtill retain the name of *Canon mills*. Other grants and privileges were beſtowed by ſucceeding ſovereigns; ſo that it was deemed the richeſt religious foundation in Scotland. At the Reformation, its annual revenues were 442 bolls of wheat, 640 bolls of bear, 560 bolls of oats, 500 capons, two dozen of hens, as many ſalmon, 12 loads of ſalt; beſides a great number of ſwine, and about 250l. ſterling in money. At the Reformation, the ſuperiority of North Leith, part of the Pleaſance, the barony of Broughton, and the Canongate, were veſted in the earl of Roxburgh; and were purchaſed from him by the town council of Edinburgh in 1636. In 1544, the church ſuffered conſiderably by the invaſion of the Engliſh; but was ſpeedily repaired. At the Reſtoration, King Charles II. ordered the church to be ſet apart as a chapel royal, and prohibited its uſe as a common pariſh church for the future. It was then fitted up in a very elegant manner. A throne was erected for the ſovereign, and 12 ſtalls for the knights of the order of the thiſtle: but as maſs had been celebrated in it in the reign of James VII. and it had an organ, with a ſpire, and a fine chime of bells on the weſt ſide, the Preſbyterians at the Revolution entirely deſtroyed its ornaments, and left nothing but the bare walls.—Through time, the roof of the church became ruinous; on which the duke of Hamilton repreſented its condition to the barons of exchequer, and craved that it might be repaired. This requeſt was complied with: but the architect and maſon who were employed, covered the roof with thick flag ſtones, which ſoon impaired the fabric; and on the 2d of December 1768, the roof fell in. Since that time, no attempt has been made to repair it, and it is now entirely fallen to ruin.

The ruins of this church, however, are ſtill ſufficient to diſcover the excellency of the workmanſhip. Here ſome of the kings of Scotland are interred; and an odd kind of curioſity has been the occaſion of expoſing ſome bones ſaid to be thoſe of Lord Darnley and a counteſs of Roxburgh who died ſeveral hundred years ago. Thoſe ſaid to belong to the former were very large, and the latter had ſome fleſh dried upon them. The chapel was fitted up in the elegant manner above mentioned by James VII. but ſuch was the enthuſiaſm of the mob, that they not only deſtroyed the ornaments, but tore up even the pavement, which was of marble.

To the eaſtward of the palace is the bowling green, now entirely in diſorder; and behind it is a field called *St Ann's Yards*. Beyond this is a piece of ground called *the King's Park;* which undoubtedly was formerly overgrown with wood, though now there is not a ſingle tree in it. It is about three miles in circumference; and was firſt encloſed by James V. It contains the rocky hills of *Atrhur's Seat* and Saliſbury Craigs, which laſt afford an inexhauſtible ſtone quarry; and upon the north ſide of the hill ſtands an old ruinous chapel, dedicated to St Anthony. The ſtones are uſed in building, as well as for paving the ſtreets and highways. The park was mortgaged to the family of Haddington for a debt due to them; and by the preſent earl has been divided into a number of encloſures by ſtone dykes raiſed at a conſiderable expence. A good number of ſheep and ſome black cattle are fed upon it; and it is now rented at 1500l. annually.

3. *St Giles's Church*, is a beautiful Gothic building, meaſuring in length 206 feet. At the weſt end, its breadth is 110; in the middle, 129; and at the eaſt end, 76 feet. It has a very elevated ſituation, and is adorned with a lofty ſquare tower; from the ſides and corners of which riſe arches of figured ſtone work: theſe meeting with each other in the middle, complete the figure of an imperial crown, the top of which terminates in a pointed ſpire. The whole height of this tower is 161 feet.

This is the moſt ancient church in Edinburgh. From a paſſage in an old author called *Simeon Dunelmenſis*, ſome conjecture it to have been built before the year 854; but we do not find expreſs mention made of it before 1359. The tutelar ſaint of this church, and of Edinburgh, was St Giles, a native of Greece. He lived in the ſixth century, and was deſcended of an illuſtrious family. On the death of his parents, he gave all his eſtate to the poor; and travelled into France, where he retired into a wilderneſs near the conflux of the Rhone with the ſea, and continued there three years. Having obtained the reputation of extraordinary ſanctity, various miracles were attributed to him; and he founded a monaſtery in Languedoc, known long after by the name of *St Giles's*.—In the reign of James II. Mr Preſton of Gorton, a gentleman whoſe deſcendants ſtill poſſeſs an eſtate in the county of Edinburgh, got poſſeſſion of the arm of this ſaint; which relick he bequeathed to the church of Edinburgh. In gratitude for this donation, the magiſtrates granted a charter in favour of Mr Preſton's heirs, by which the neareſt heir of the name of Preſton was entitled to carry it in all proceſſions. At the ſame time, the magiſtrates obliged themſelves to found an altar in the church of St Giles's, and appoint a chaplain for celebrating an annual maſs for the ſoul of Mr Preſton; and likewiſe, that a tablet, containing his arms, and an account of his pious donation, ſhould be put up in the chapel.—St Giles's was firſt ſimply a pariſh church, of which the biſhop of Lindisfarn or Holy Iſland, in the county of Northumberland, was patron. He was ſucceeded in the patronage by the abbot and canons of Dunfermline, and they by the magiſtrates of Edinburgh. In 1466, it was erected into a collegiate church by James III. At the Reformation, the church was, for the greater convenience, divided into ſeveral parts. The four principal ones are appropriated to divine worſhip, the leſſer ones to other purpoſes. At the ſame time the religious utenſils belonging to this church were ſeized by the magiſtrates. They were,—St Giles's arm, enſhrined in ſilver, weighing five pounds three ounces and a half; a ſilver chalice, or communion cup, weighing 23 ounces; the great *euchariſt* or communion cup, with *golden weike and ſtones;* two cruets of 25 ounces; a golden bell, with a heart, of four ounces and a half; a golden unicorn; a golden pix, to keep the hoſt; a ſmall golden heart, with two pearls; a diamond ring; a ſilver chalice, patine, and ſpoon, of 32 ounces and a half: a communion table cloth of gold brocade; *St Giles's coat*, with a little piece of red velvet which hung at his feet; a round ſilver *euchariſt;* two ſilver cenſers, of three pounds fifteen ounces; a ſilver ſhip for incenſe; a large ſilver croſs, with its baſe, weighing ſixteen pounds thirteen ounces and a half; a triangular ſilver lamp; two ſilver candleſticks, of ſeven pounds three ounces; other two, of eight pounds thirteen ounces; a ſilver chalice gilt, of $20\frac{1}{4}$ ounces; a ſilver chalice and croſs, of 75 ounces; beſides the prieſts robes, and other veſtments, of gold brocade, crimſon velvet embroidered with gold, and green damaſk.—Theſe were all ſold, and part of the money applied to the repairs of the church; the reſt was added to the funds of the corporation.

In the ſteeple of St Giles's church are three large bells brought from Holland in 1621; the biggeſt weighing 2000lb. the ſecond 700, and the third 500. There are alſo a ſet of muſic bells, which play every day between one and two o'clock, or at any time in the caſe of rejoicings. The cathedral is divided by partition walls; and the principal apartments are uſed as four ſeparate churches, which are diſtinguiſhed by the names of the *New* or *High Church*, the *Old Church*, the *Tolbooth Church*, which is contiguous to the priſon, and the *Little Church*, or *Haddow's Hole Church*, which derives its latter name from a gentleman who had been confined in it. The principal diviſion is called the *High Church*, which has been elegantly repaired and new ſeated. There is a very elegant and finely ornamented ſeat for his majeſty, with a canopy ſupported by four Corinthian pillars decorated in high taſte. This ſeat is uſed by the king's commiſſioner during the time the General Aſſembly ſits. On the right hand is a ſeat for the lord high conſtable of Scotland, whoſe office it is to keep the peace within doors in his majeſty's preſence; it being the duty of the earl marſhal to do the ſame without. The ſeats belonging to the lords of council and ſeſſion are on the right of the lord high conſtable; and on the left of the throne was a ſeat for the lord high chancellor of Scotland; but that office being now aboliſhed, the ſeat is occupied by others. On the left of this ſit the barons of exchequer; and, to the left of them, the lord provoſt, magiſtrates,

and

and town council. The pulpit, king's ſeat, and galleries, are covered with crimſon velvet with gold and ſilk fringes.

The aiſle of St Giles's church is fitted up with ſeats for the general aſſembly who meet here; and there is a throne for his majeſty's commiſſioner with a canopy of crimſon ſilk damaſk, having the king's arms embroidered with gold, preſented by the late Lord Cathcart to his ſucceſſor in office. In this church is a monument dedicated to the memory of Lord Napier, baron of Merchiſton, well known as the inventor of logarithms; a ſecond to the earl of Murray, regent of Scotland during the minority of James VI.; and a third to the great marquis of Montroſe.

4. *The Parliament Houſe*, in the great hall of which the Scottiſh parliament uſed to aſſemble, is a magnificent building. The hall is 123 feet long and 42 broad, with a fine arched roof of oak, painted and gilded. In this the lawyers and agents now attend the courts, and ſingle judges ſit to determine cauſes in the firſt inſtance, or to prepare them for the whole court, who ſit in an inner room formerly appropriated to the privy council. This inner apartment has been lately repaired and very commodiouſly fitted up. In a niche of the wall is placed a fine marble ſtatue of Preſident Forbes, erected at the expence of the faculty of advocates. There are alſo full-length portraits of King William III. Queen Mary his conſort, and Queen Anne, all done by Sir Godfrey Kneller; alſo of George I. John duke of Argyll and Archibald duke of Argyll, by Mr Aikman of Cairney.

Above ſtairs were formerly the court of exchequer and treaſury chamber, with the different offices belonging to that department; but theſe were removed in 1803 to the apartments in the royal exchange occupied by the cuſtomhouſe; and below is one of the moſt valuable libraries in Great Britain, belonging to the faculty of advocates. Beſides 30,000 printed volumes, there are many ſcarce and valuable manuſcripts, medals, and coins: here is alſo an entire mummy in its original cheſt, preſented to the faculty (at the expence of 300l.) by the earl of Morton, late preſident to the Royal Society. As theſe rooms are immediately below the hall where the parliament ſat, they are ſubject to a ſearch by the lord high conſtable of Scotland ever ſince the gunpowder plot; and this is ſpecified in the gift from the city to the faculty. This library was founded, in the year 1682, by Sir George Mackenzie lord advocate. Among other privileges, it is entitled to a copy of every book entered in Stationers hall. Before the great door is a noble equeſtrian ſtatue of Charles II. the proportions of which are reckoned exceedingly juſt. Over the entrance are the arms of Scotland, with Mercy and Truth on each ſide for ſupporters.

The court of ſeſſion, the ſupreme tribunal in Scotland, conſiſts of 15 judges, who ſit on a circular bench, clothed in purple robes turned up with crimſon velvet. Six of theſe are lords of the juſticiary, and go the circuit twice a-year; but, in that capacity, they wear ſcarlet robes turned up with white ſatin.

5. *The Tolbooth* was erected in 1561, not for the purpoſes merely of a priſon, but likewiſe for the accommodation of the parliament and other courts; but it has ſince become ſo very unfit for any of theſe purpoſes, that it is now propoſed to pull it down, and rebuild it in ſome other place, eſpecially as it is very inconvenient in its preſent ſituation on account of its encumbering the ſtreet. The provoſt is captain of the tolbooth, with a gaoler under him: and the latter has a monopoly of all the proviſions for the priſoners; a circumſtance which muſt certainly be conſidered as a grievous oppreſſion, thoſe who are leaſt able to purchaſe them being thus obliged to do ſo at the higheſt price. There is a chaplain who has a ſalary of 30l. a-year.

6. *Bridewell.* "On the Calton-hill, to be ſeen from the North Bridge, is a correction-houſe or *Bridewell*, built within theſe few years. It is a ſtrong ſtone fabric. The principal part of the building is in the form of the letter D, with a houſe for the governor at ſome diſtance oppoſite to the northern or rectilineal part of it. The whole is ſurrounded by lofty walls, betwixt which and the houſe is an area laid out as a garden.

"This is ſaid to be one of the moſt complete buildings of the kind in Britain. It conſiſts of five ſtories; the uppermoſt of which is uſed as an hoſpital for ſick priſoners and for ſtore-rooms, &c. The other four ſtories are laid out in the following manner: A paſſage goes along the middle of the ſemicircular part of the building with apartments on each hand. The apartments on the outward ſide of the curvature are ſmaller than thoſe on the inner ſide. They are double the number, and are uſed as ſeparate bed-chambers for each of the perſons confined. The apartments on the inner ſide of the ſemicircle, of which there are thirteen in each ſtory, are allotted for labour. They have a grate in front, and look into the inner court. Oppoſite to them, in the flat ſide of the building, is a dark apartment with narrow windows, from which, without being ſeen, the governor can ſee how the priſoners in the apartments for work are employed. The court, or ſpace in the middle between the flat and ſemicircular part of the building, is roofed in at the top; and a great part of it is covered with glaſs, ſo as to light the whole. On the floor of the area is a ſtove, which during winter heats the whole apartments allotted to labour. There is alſo a pulpit, from which a chaplain preaches on Sundays; and the priſoners come into the front apartments to attend the ſervice.

"The bed-chambers, looking outwards to the country, are lighted by a long narrow window in each. The window is glazed. The frame in which the glaſs is fixed is of iron. It turns on pivots fixed at the top and bottom, ſo as to be opened and ſhut at pleaſure. Each bed-chamber, which is about eight feet long by ſeven broad, is furniſhed with a bed and a bible. The frame of the bed is of iron, the bed conſiſts of a ſtraw mattreſs of the beſt quality. The whole floors and partitions of the building are of ſtone. No wood is uſed excepting for the doors of the apartments. There are cells, however, for ſolitary confinement for male criminals, in which the frames of the beds are of wood, leſt, by breaking them, tools or weapons of a dangerous nature ſhould be obtained. Large ciſterns, ſupplied with water from the city's reſervoir, are placed at the top of the houſe, from which the water is diſtributed to the different ſtories, and to a kitchen, waſhing houſe, and baths, on the ground floor.

"The inſtitution is managed with great care. Beſides being ſuperintended by the magiſtrates of Edinburgh, the

the ſheriff of the county once each month viſits every corner of it. It is kept in a ſtate of the moſt perfect cleanneſs. The priſoners, when firſt received, are clothed in a uniform belonging to the place; and their own clothes, after being cleaned, are preſerved for them till their diſmiſſion. They remain during the day in the apartments allotted to labour, from which they are always diſmiſſed as ſoon as it becomes dark to their bedchambers. The women ſpin, and the men pick oakum. Their food conſiſts of oatmeal porridge with ſmall beer for breakfaſt and ſupper; and for dinner, of broth made of fat and vegetables, reſembling what in Scotland is called *ſhearer's kail* (reaper's broth). Thoſe that exert any tolerable induſtry are allowed bread to their broth, and alſo a larger portion of porridge. Only one death has occurred in the houſe during the laſt four years; and in that caſe the individual who died had come into Bridewell under a complication of diſeaſes. In truth, the food, clothing, good air, and comfortable lodging, which are enjoyed in this place, are far ſuperior to what the greater number of inhabitants can expect to obtain on their return to the world at large. To reſide here, therefore, is a puniſhment from moral and not from phyſical cauſes; that is to ſay, becauſe it is attended with the loſs of freedom and of ſociety, and becauſe it is a place of infamy."

Beauties of Scotland, vol. i. p. 114.

7. There is a hall in the Writers Court belonging to the clerks to his majeſty's ſignet, where there is alſo an office for the buſineſs of the ſignet. The office of keeper of the ſignet is very lucrative, and he is allowed a depute and clerks under him. Before any one enters into this ſociety he muſt attend the college for two years, and ſerve five years as an apprentice to one of the ſociety. There is a very excellent library belonging to this hall, which is rapidly increaſing, as every one who enters muſt pay 10l. towards it. He pays alſo 100l. of apprentice fee, and 100l. when he enters.

8. *The Exchange* is a large and elegant building, with a court of about 90 feet ſquare in the middle. On the north ſide are piazzas where people can walk under cover, the other three ſides being laid out in ſhops; but the merchants have never made uſe of it to meet in, ſtill ſtanding in the ſtreet as formerly. The back part of the building formerly uſed for the general cuſtomhouſe of Scotland, where the commiſſioners met to tranſact buſineſs, is now occupied by the offices connected with the Exchequer. They had above 20 offices for the different departments, to which the acceſs is by a hanging ſtair 60 feet in height. In looking over the window before he aſcends this ſtair, a ſtranger is ſurpriſed to find himſelf already 40 feet from the ground, which is owing to the declivity on which the Exchange is built. The fine manſion of Bellevue north of the New Town is now converted into apartments for the cuſtomhouſe.

The Truſtees Office for the improvement of fiſheries and manufactures in Scotland is in the ſouth-weſt corner of the Exchange; the fund under their management being part of the equivalent money given to Scotland at the Union. This is diſtributed in premiums amongſt thoſe who appear to have made any conſiderable improvement in the arts.

9. *The North Bridge*, which forms the main paſſage of communication betwixt the Old and New Towns, was founded, as has already been obſerved, in 1763 by Provoſt Drummond; but the contract for building it was not ſigned till Auguſt 21. 1765. The architect was Mr William Mylne, who agreed with the town council of Edinburgh to finiſh the work for 10,140l. and to uphold it for 10 years. It was alſo to be finiſhed before Martinmas 1769: but on the 3d of Auguſt that year, when the work was nearly completed, the vaults and ſide walls on the ſouth fell down, and five people were buried in the ruins. This misfortune was occaſioned by the foundation having been laid, not upon the ſolid earth, but upon the rubbiſh of the houſes which had long before been built on the north ſide of the High ſtreet, and which had been thrown out into the hollow to the northward. Of this rubbiſh there were no leſs than eight feet between the foundation of the bridge and the ſolid earth. Beſides this deficiency in the foundation, an immenſe load of earth which had been laid over the vaults and arches in order to raiſe the bridge to a proper level, had no doubt contributed to produce the cataſtrophe above mentioned.—The bridge was repaired, by pulling down ſome parts of the ſide walls, and afterwards rebuilding them; ſtrengthening them in others with chain bars; removing the quantity of earth laid upon the vaults, and ſupplying its place with hollow arches, &c. The whole was ſupported at the ſouth end by very ſtrong buttreſſes and counterforts on each ſide; but on the north it has only a ſingle ſupport.—The whole length of the bridge, from the High ſtreet in the Old Town to Prince's ſtreet in the New, is 1125 feet; the total length of the piers and arches is 310 feet. The width of the three great arches is 72 feet each; of the piers, 13½ feet; and of the ſmall arches, each 20 feet. The height of the great arches, from the top of the parapet to the baſe, is 68 feet; the breadth of the bridge within the wall over the arches is 40 feet, and the breadth at each end 50 feet.—On the ſouthern extremity of this bridge ſtands the General Poſt Office for Scotland; a neat plain building, with a proper number of apartments for the buſineſs, and a houſe for the ſecretary.

The communication betwixt the two towns by means of this bridge, though very complete and convenient for ſuch as lived in certain parts of either, was yet found inſufficient for thoſe who inhabit the weſtern diſtricts. Another bridge being therefore neceſſary, it was propoſed to fill up the valley occaſionally with the rubbiſh dug out in making the foundations of houſes in the New Town; and ſo great was the quantity, that this was accompliſhed ſo as to be fit for the paſſage of carriages in little more than four years and a half.

10. *The South Bridge* is directly oppoſite to the other, ſo as to make but one ſtreet, croſſing that called the *High Street* almoſt at right angles. It conſiſts of 19 arches of different ſizes: but only one of them is viſible, viz. the large one over the Cowgate; and even this is ſmall in compariſon with thoſe of the North Bridge, being no more than 30 feet wide and 31 feet high. On the ſouth it terminates at the Univerſity on one hand, and the Royal Infirmary on the other. The Tron Church, properly called *Chriſt Church*, ſtands at the northern extremity, facing the High ſtreet, and in the middle of what is now called *Hunter's Square*, in memory of the worthy chief magiſtrate who planned thoſe improvements, but did not live to ſee them executed.

executed. On the weſt ſide of this ſquare the Merchant Company have built a very handſome hall for the occaſional meetings of their members. This bridge was erected with a deſign to give an eaſy acceſs to the great number of ſtreets and ſquares on the ſouth ſide, as well as to the country on that quarter from whence the city is ſupplied with coals. The ſtreet on the top is ſuppoſed to be as regular as any in Europe; every houſe being of the ſame dimenſions, excepting that between every two of the ordinary conſtruction there is one with a pediment on the top, in order to prevent that ſameneſs of appearance which would otherwiſe take place. So great was the rage for purchaſing ground on each ſide of this bridge for building, that the areas ſold by public auction at 50l. per foot in front. By this the community will undoubtedly be conſiderable gainers; and the proprietors hope to indemnify themſelves for their extraordinary expence by the vaſt ſale of goods ſuppoſed to attend the ſhops in that part of the town; though this ſeems ſomewhat more dubious than the former.

11. The *Concert Hall*, called alſo *St Cecilia's Hall*, ſtands in Niddery's ſtreet; and was built in 1762, after the model of the great opera theatre in Parma. The plan was drawn by Sir Robert Mylne, architect of Blackfriars bridge. The muſical room is of an oval form, the ceiling being a concave elliptical dome, lighted from the top by a lanthorn. The ſeats are ranged in the form of an amphitheatre; and are capable of containing 500 perſons, beſides leaving a large area in the middle of the room. The orcheſtra is at the upper end, and is terminated by an elegant organ.

The muſical ſociety was firſt inſtituted in the year 1728. Before that time, ſeveral gentlemen had formed a weekly club at a tavern kept by one Steil, a great lover of muſic, and a good ſinger of Scots ſongs. Here the common entertainment conſiſted in playing on the harpſichord and violin the concertos and ſonatas of Handel, juſt then publiſhed. The meeting, however, ſoon becoming numerous, they inſtituted, in the year above mentioned, a ſociety of 70 members, for the purpoſe of holding a weekly concert. The affairs of the ſociety were regulated by a governor, deputy-governor, treaſurer, and five directors, who were annually choſen by the members. The meetings were continued ever ſince that time on much the ſame footing as at firſt, and the number of members increaſed to 200. The weekly concerts were on Friday; the tickets being given gratis by the directors, and attention paid in the firſt place to ſtrangers. Oratorios were occaſionally performed throughout the year; and the principal performers had alſo benefit concerts. The band were excellent in their ſeveral departments; and ſeveral of the members being alſo good performers, took their part in the orcheſtra. There were always many applications on the occaſion of a vacancy; and ſuch was generally the number of candidates, that it was no eaſy matter to be admitted. This ſociety, however, has been long neglected, and the hall diſpoſed of for other purpoſes.

12. *The Univerſity.* In the year 1581, a grant was obtained from King James VI. for founding a college or univerſity within the city of Edinburgh; and the citizens, aided by various donations from well-diſpoſed perſons, purchaſed a ſituation for the intended new college, conſiſting of part of the areas, chambers, and church of the collegiate provoſtry and prebends of the Kirk-a-field, otherwiſe called *Templum et Præfectura Sanctæ Mariæ in campis*, lying on the ſouth ſide of the city. Next year, a charter of confirmation and erection was obtained alſo from King James VI. from which the college to be built did afterwards derive all the privileges of an univerſity.

In 1583, the provoſt, magiſtrates, and council, the patrons of this new inſtitution, prepared the place in the beſt manner they could for the reception of teachers and ſtudents; and in the month of October the ſame year, Robert Rollock, whom they had invited from a profeſſorſhip in St Salvator's College in the univerſity of St Andrew's, began to teach in the new college of Edinburgh. Other profeſſors were ſoon after elected; and in the year 1586, Rollock was appointed principal of the college, and the following year alſo profeſſor of divinity, immediately after he had conferred the degree of M. A. on the ſtudents who had been under his tuition for four years. The offices of principal and profeſſor of divinity remained united till the year 1620.

In the 1617, King James VI. having viſited Scotland after his acceſſion to the crown of England, commanded the principal and regents of the college of Edinburgh to attend him in Stirling caſtle; and after they had there held a ſolemn philoſophical diſputation in the royal preſence, his majeſty was ſo much ſatiſfied with their appearance, that he deſired their college for the future might be called *The College of King James*, which name it ſtill bears in all its diplomas or public deeds.

For ſeveral years the college conſiſted only of a principal, who was alſo profeſſor of divinity, with four regents or profeſſors of philoſophy. Each of theſe regents inſtructed one claſs of ſtudents for four years, in Latin, Greek, ſchool logic, mathematics, ethics, and phyſics, and graduated them at the concluſion of the fourth courſe. A profeſſor of humanity or Latin was afterwards appointed, who prepared the ſtudents for entering under the tuition of the regents; alſo a profeſſor of mathematics, and a profeſſor of Hebrew or Oriental languages. It was not till about the year 1710 that the four regents began to be confined each to a particular profeſſion; ſince which time they have been commonly ſtyled *Profeſſors of Greek, Logic, Moral Philoſophy, and Natural Philoſophy*.—The firſt medical profeſſors inſtituted at Edinburgh, were Sir Robert Sibbald and Doctor Archibald Pitcairn, in the year 1685 *. Theſe, however, were only titular profeſſors; and for 30 years afterwards, a ſummer lecture on the officinal plants, and the diſſection of a human body once in two or three years, completed the whole courſe of medical education at Edinburgh. In 1720, an attempt was made to teach the different branches of phyſic regularly; which ſucceeded ſo well, that ever ſince, the reputation of the univerſity as a ſchool for medicine hath been conſtantly increaſing, both in the iſland of Britain, and even among diſtant nations.

The college is endowed with a very fine library, founded in 1580 by Mr Clement Little advocate, who bequeathed it to the town council. They ordered a houſe to be built for it in the neighbourhood of St Giles's church, where it was for ſome time kept under

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* See *College of Phyſicians*.

under the care of the eldeſt miniſter of Edinburgh, but was afterwards removed to the college. This collection is enriched, as well as others of a ſimilar kind, by receiving a copy of every book entered in Stationers hall, according to the ſtatute for the encouragement of authors. Beſides this, the only fund it has is the money paid by all the ſtudents at the univerſity, except thoſe of divinity, upon their being matriculated; and a ſum of 5l. given by each profeſſor at his admiſſion. The amount of theſe ſums is uncertain, but has been eſtimated at about 150l. annually. The ſtudents of divinity, who pay nothing to this library, have one belonging to their own particular department.

Here are ſhown two ſkulls, one almoſt as thin as paper, pretended to be that of the celebrated George Buchanan; and, by way of contraſt, another ſaid to have been that of an idiot, and which is exceſſively thick. Here alſo are preſerved the original proteſt againſt the council of Conſtance for burning John Huſs and Jerome of Prague in 1417; the original contract of Queen Mary with the dauphin of France, and ſome valuable coins and medals. There are alſo ſeveral portraits; particularly of Robert Pollock the firſt principal of the univerſity, King James VI. John Napier the inventor of logarithms, John Knox, Principal Carſtairs, Mr Thomſon the author of the Seaſons, &c. The muſeum contains a good collection of natural curioſities, the number of which is daily increaſing. The anatomical preparations are worth notice, as are alſo thoſe belonging to the profeſſor of midwifery.

The celebrity of this college has been greatly owing to the uniform attention of the magiſtracy in filling up the vacant chairs with men of known abilities in their reſpective departments.

The univerſity of Edinburgh "having been inſtituted after the Reformation, among a frugal people that had no love for eccleſiaſtical dignities, it differs greatly from the wealthy foundations which receive the name of *univerſities* and *colleges* in England, or in the catholic countries of the continent of Europe. The univerſity of Edinburgh conſiſts of a ſingle college, which enjoys the privilege of conferring degrees. It conſiſts of a principal, with a ſalary of 111l. 2s. $0\frac{2}{3}$d. whoſe office is in a great meaſure nominal, and of a profeſſor in each of the following departments:

Faculty of Theology.

	Salaries.		
Divinity - -	L. 161	2	$0\frac{2}{3}$
Church Hiſtory - -	100	0	0
Oriental Languages - -	119	12	8

Faculty of Law.

Law of Nature and Nations.—Salary variable, but always above -	300	0	0
Civil Law - - -	100	0	0
Scots Law - -	100	0	0
Civil Hiſtory and Antiquities -	100	0	0

Faculty of Medicine.

	Salaries.		
Anatomy and Surgery -	50	0	0
Practice of Medicine - -		—	—
Botany - -	77	15	$6\frac{2}{3}$
Materia Medica - -		—	—
Chemiſtry - - -		—	—
Theory of Medicine - -		—	—
Midwifery - - -		—	—
Natural Hiſtory - -		—	—

Faculty of Arts.

Moral Philoſophy - -	102	4	$5\frac{1}{3}$
Rhetoric and Belles Lettres -	70	0	0
Greek - - -	52	4	$5\frac{1}{3}$
Latin - - -	52	10	0
Natural Philoſophy - -	52	4	$5\frac{2}{3}$
Mathematics - -	113	6	8
Practical Aſtronomy - -	100	0	0
Logic - - -	52	4	$5\frac{1}{3}$
Agriculture - - -	50	0	0

"Of theſe, the profeſſors of church hiſtory and natural hiſtory, aſtronomy, law of nature and nations, and rhetoric, are in the gift of the crown. The profeſſor of agriculture was nominated by Sir William Pultney, founder of the inſtitution. The remaining chairs are in the gift of the town-council of Edinburgh. Beſides theſe claſſes here enumerated, the medical profeſſors alternately give clinical lectures upon the caſes of the patients in the royal infirmary of Edinburgh."

Beauties of Scotland, I. 45.

The univerſity is now attended by not leſs than from 1200 to 1400 ſtudents in the different departments of ſcience and literature.

The old buildings being very mean, and unfit for the reception of ſo many profeſſors and ſtudents, and quite unſuitable to the dignity of ſuch a flouriſhing univerſity, as well as inconſiſtent with the improved ſtate of the city, the Lord Provoſt, Magiſtrates, and Council, ſet on foot a ſubſcription for erecting a new ſtructure, according to a deſign of Robert Adam, Eſq. architect. Part of the old fabric has in conſequence been pulled down, and the new building is already in conſiderable forwardneſs. The foundation ſtone was laid on Monday the 16th of November, with great ſolemnity, by the Right Hon. Francis Lord Napier, grand maſter maſon of Scotland, in the preſence of the Right Hon. the Lord Provoſt, Magiſtrates, and Town Council of the city of Edinburgh, with the principal, profeſſors, and ſtudents of the univerſity of Edinburgh, a number of nobility and gentry, and the maſters, officers, and brethren of all the lodges of free maſons in the city and neighbourhood, who marched in proceſſion from the Parliament Houſe down the High ſtreet. After the different maſonic ceremonials were performed, two cryſtal bottles, caſt on purpoſe at the glaſs houſe of Leith, were depoſited in the foundation ſtone. In one of theſe were put different coins of the preſent reign, each of them being previouſly enveloped in cryſtal, in ſuch an ingenious manner, that the legend on the coins could be diſtinctly read without breaking the cryſtal. In the other bottle were depoſited ſeven rolls of vellum, containing a ſhort account of the original foundation and preſent ſtate of the univerſity, together with ſeveral other papers, in particular the different newſpapers, containing advertiſements relative to the college, &c. and a liſt of the names of the principal and profeſſors, alſo of the preſent lord provoſt and magiſtrates, and officers of the

the grand lodge of Scotland. The bottles being carefully ſealed up, were covered with a plate of copper wrapt in block tin; and upon the under ſide of the copper were engraved the arms of the city of Edinburgh and the univerſity; likewiſe the arms of the Right Hon. Lord Napier, grand maſter maſon of Scotland. Upon the upper ſide, a Latin inſcription, of which the following is a copy:

ANNUENTE DEO OPT. MAX.
REGNANTE GEORGIO III. PRINCIPE
MUNIFICENTISSIMO;
ACADEMIÆ EDINBURGENSIS
ÆDIBUS,
INITIO QUIDEM HUMILLIMIS,
ET JAM, POST DUO SECULA, PENE RUINOSIS;
NOVI HUJUS ÆDIFICII,
UBI COMMODITATI SIMUL ET ELEGANTIÆ,
TANTO DOCTRINARUM DOMICILIO
DIGNÆ,
CONSULERETUR,
PRIMUM LAPIDEM POSUIT,
PLAUDENTE INGENTI OMNIUM ORDINUM
FREQUENTIA,
VIR NOBILISSIMUS
FRANCISCUS DOMINUS NAPIER,
REIPUB. ARCHITECTONICÆ APUD SCOTOS
CURIO MAXIMUS:
XVI. KAL. DECEMB.
ANNO SALUTIS HUMANÆ MDCCLXXXIX.
ÆRÆ ARCHITECTONICÆ IↃↃIↃCCLXXXIX.
CONSULE THOMA ELDER,
ACADEMIÆ PRÆFECTO GULIELMO
ROBERTSON,
ARCHITECTO ROBERTO ADAM.
Q. F. F. Q. S.

The eaſt and weſt fronts of this pile are to extend 255 feet, and the ſouth and north 358. There are to be houſes for the principal and ſix or ſeven of the profeſſors. The library is to be a room of 160 feet in length; the muſeum for natural curioſities is to be of the ſame extent; and the dimenſions of the hall for degrees and public exerciſes are about 90 feet by 30. There are likewiſe to be an elegant and moſt convenient anatomical theatre *; a chemical laboratory; and large rooms for inſtruments and experiments for the profeſſors of mathematics, natural philoſophy, and agriculture. The whole, when finiſhed, if not the moſt ſplendid ſtructure of the ſort in Europe, will however be the completeſt and moſt commodious. The progreſs of the building has now (1804) ſtopped. The front was completed by the aid of royal munificence; but after an expenditure of 50,000l. it is ſuppoſed that not more than one third of the plan has been executed.

The botanical garden belonging to the univerſity is ſituated at the diſtance of about a mile, on the road between Edinburgh and Leith. It conſiſts of about five acres of ground; and is furniſhed with a great variety of plants, many of them brought from the moſt diſtant quarters of the globe. The profeſſor is botaniſt to the king, and receives a ſalary of 120l. annually for the ſupport of the garden. A monument, to the memory of the celebrated botaniſt Linnæus, was erected here by the late Dr Hope, who firſt planned the garden, and brought it to perfection.

The univerſity of Edinburgh, like the others in this kingdom, ſends one member to the General Aſſembly of the church of Scotland; and the widows of the profeſſors have a right to the funds of thoſe of miniſters, the profeſſors being truſtees on that fund along with the preſbytery of Edinburgh.

"In the year 1772, the Board of Truſtees for the encouragement of Manufactures, &c. in Scotland, appointed Mr Alexander Runciman, painter, to teach 20 boys or girls drawing, allowing him a yearly ſalary of 120l. He was ſucceeded in this office by Mr Allan, to whom followed Mr Graham. This inſtitution being appropriated for the uſe of manufactures, is not properly a ſchool of painting. In this laſt art, however, very eminent teachers are to be found in Edinburgh, but no public eſtabliſhment exiſts for its encouragement.

"Near the Univerſity there is alſo a *Riding School*, called the *Royal Academy for teaching Exerciſes*. The teacher of this academy receives a ſalary of 200l. a-year from the crown, and is accommodated with a riding ſchool of 120 feet in length by 40 in breadth, and ſtables to a conſiderable extent.

"In Edinburgh there is eſtabliſhed, in imitation of that in London, a *Royal Society*, which has publiſhed ſome volumes of tranſactions. It contains a number of members of great reſpectability; but in Edinburgh men of letters are apt to be extremely jealous and unſociable with regard to each other. This illiberality of temper prevents the Royal Society from being of much value. Great numbers of the moſt accompliſhed and active men of letters are unconnected with it, while it contains others who have been introduced to it merely by their rank in the world, or the circumſtance of having attained to diſtinguiſhed literary ſituations by the patronage of men in power, who of late years have, in this country, diſplayed little of that anxiety to diſcriminate and bring into notice men of literary talents, which once formed the moſt honourable characteriſtic of the nobles and ſtateſmen of Scotland." *Beauties of Scotland*, I. 59.

13. *The Royal Infirmary* was firſt thought of by the College of Phyſicians in 1725. A fiſhing company happening to be diſſolved at that time, the partners contributed ſome of their ſtock towards the eſtabliſhment of the Infirmary. A ſubſcription was alſo ſet on foot, and application made to the General Aſſembly to recommend the ſame throughout their juriſdiction. This was readily complied with, and the aſſembly paſſed an act for that purpoſe; but very little regard was paid to it by the clergy. Notwithſtanding this, however, 2000l. being procured, a ſmall houſe was opened for the reception of the ſick poor in Auguſt 1729. In 1736, the contributors towards the Infirmary were erected into a body corporate by royal ſtatute; and after this the contributions increaſed very conſiderably: by which means the managers were enabled to enlarge their ſcheme from time to time; and at laſt to undertake the preſent magnificent ſtructure, the foundation of which was laid in 1738. During 25 years, when this inſtitution was in its infancy, Lord Hopetoun beſtowed upon it an annuity of 400l. In 1750, Doctor Archibald Ker bequeathed to this incorporation 200l. a-year in the iſland of Jamaica. In 1755, the

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* *This is now finiſhed.*

lords of the treaſury made a donation to it of 8000l. which had been appointed for the ſupport of invalids. In return for this, the managers of the Infirmary conſtantly keep 60 beds in readineſs for the reception of ſick ſoldiers. This year alſo ſick ſervants began to be admitted into the Infirmary, and a ward was fitted up for their reception.

This inſtitution, however, was more indebted to George Drummond, Eſq. than to any other perſon. He was ſeven times choſen lord provoſt of Edinburgh; and always directed his attention to the improvement of the city, particularly to that of the Royal Infirmary. So ſenſible were the managers of their obligations to him, that, in their hall, they erected a buſt of him with this inſcription, "George Drummond, to whom this country is indebted for all the benefit which it derives from the Royal Infirmary."—In 1748, the ſtock of the Infirmary amounted to 5000l.; in 1755, to 7076l. beſides the eſtate left by Doctor Ker; in 1764, to 23,426l.; and in 1778, to 27,074l.

The Royal Infirmary is attended by two phyſicians choſen by the managers, who viſit their patients daily in preſence of the ſtudents. All the members of the College of Surgeons were obliged to attend in rotation, according to ſeniority. If any ſurgeon declined attendance, he was not allowed to appoint a depute; and the patients were committed to the care of one of four aſſiſtant ſurgeons, choſen annually by the managers: this was formerly the mode of attendance, but the managers have in conſequence of a deciſion of the high court of judicature aſſumed to themſelves the ſole right of electing the ſurgeons.—From the year 1762 to 1769, there were admitted 6261 patients; which number added to 109 who were in the hoſpital at the commencement of the year 1762, made, in all, 6370. Of theſe, 4395 were cured; 358 died: the reſt were either relieved, diſmiſſed incurable, for irregularities, or by their own deſire, or remained in the hoſpital.—From 1770 to 1775, the patients annually admitted into the Infirmary were, at an average, 1567; of whom 63 died. In 1776, there were admitted 1668, of whom 57 died; and in 1777, the number admitted was 1593, and of deaths 52. In the year 1786, there were admitted 1822 patients: Of theſe 1354 were cured; 166 relieved; 84 died; the reſt were either relieved, diſmiſſed incurable, for irregularities, or by their own deſire.

The building conſiſts of a body and two wings, each of them three ſtories high, with an attic ſtory and garrets, and a very elegant front. The body is 210 feet long, and 36 broad in the middle, but at the ends only 24 feet broad. There is a buſt of King George II. in a Roman dreſs, above the great door. The wings are 70 feet long, and 25 broad. In the centre is a large ſtaircaſe, ſo wide that ſedan chairs may be carried up. In the different wards, 228 patients may be accommodated, each in a different bed. There are cold and hot baths for the patients, and alſo for the citizens; and to theſe laſt the patients are never admitted.

Beſides the apartments neceſſary for the ſick, there are others for the officers and ſervants belonging to the houſe. There are likewiſe rooms for the managers, a conſulting room for the phyſicians and ſurgeons, a waiting room for the ſtudents, and a theatre that will hold upwards of 200 people for performing chirurgical operations. There is a military ward, ſupported by the intereſt of the 8000l. already mentioned; and in conſequence of which a ſmall guard is always kept at the Infirmary. The wards for ſick ſervants are ſupported by collections at the church doors. Beſides the ſurgical attendance already mentioned, there are two phyſicians belonging to the houſe, who are elected by the managers, and have a ſalary: there is likewiſe a houſe-ſurgeon and apothecary. Students who attend the Infirmary paid formerly 3l. 3s. which is increaſed to 5l. 5s. annually, which brings in a conſiderable revenue towards defraying the expence of the houſe. Two wards are ſet apart for the patients whoſe caſes are ſuppoſed to be moſt intereſting; and the medical profeſſors in the univerſity give clinical lectures upon them by rotation.

14. *The Public Diſpenſary* was founded by Dr Duncan in 1776, for the poor whoſe diſeaſes are of ſuch a nature as to render their admiſſion into the Infirmary either unneceſſary or improper. Here the patients receive advice gratis four days in the week; a regiſter is kept of the diſeaſes of each, and of the effects produced by the medicines employed. All patients not improper for diſpenſary treatment are admitted on the recommendation of the elder or church warden of the pariſh where they reſide. The phyſicians officiate and give lectures gratis; ſo that the apothecary who lodges in the houſe, and the medicines, are the only expences attending this uſeful inſtitution. The expence of the whole is defrayed by public contributions, and from a ſmall annual fee paid by the ſtudents who attend the lectures. It is under the direction of a preſident, two vice-preſidents, and 20 directors, elected annually from among the contributors. One guinea entitles a contributor to recommend patients and be a governor for two years, and five guineas gives the ſame privilege for life. Under the ſame management there is an inſtitution for the gratuitous inoculation for the cowpox.

15. *The High School.* The earlieſt inſtitution of a grammar ſchool in Edinburgh ſeems to have been about the year 1519. The whole expence beſtowed upon the firſt building of this kind amounted only to about 40l. ſterling. Another building, which had been erected for the accommodation of the ſcholars in 1578, continued, notwithſtanding the great increaſe of their number, to be uſed for that purpoſe till 1777. The foundation of the preſent new building was laid on the 24th of June that year by Sir William Forbes, Grand Maſter of the Free Maſons. The total length of this building is 120 feet from ſouth to north; the breadth in the middle 36, at each end 38 feet. The great hall where the boys meet for prayers, is 68 feet by 30. At each end of the hall is a room of 32 feet by 20, intended for libraries. The building is two ſtories high, the one 18, the other 17, feet in height. The expence of the whole was reckoned at 4000l.

There is a rector and four maſters, who teach from 400 to 500 ſcholars annually. The ſalaries are trifling, and the fees depend upon the reputation they have obtained for teaching; and as this has been for ſome years very conſiderable, the rector's place is ſuppoſed to be worth not leſs than 400l. per annum, a maſter's about half that ſum. There is a janitor, whoſe place is ſuppoſed to be worth about 70l. a-year. His buſineſs is to take care of the boys on the play ground; and there is a woman who lives on the ſpot as under-janitor, whoſe place may be worth about 25l. annually. There is a library, but not large, as each of the boys pays only one ſhilling annually to its ſupport.

There are four eſtabliſhed Engliſh ſchools in Edinburgh; the maſters of which receive a ſmall ſalary, upon expreſs condition that they ſhall not take above a limited ſum per quarter from any of their ſcholars. There are likewiſe many other private ſchools in Edinburgh for all languages; and, in general, every kind of education is to be had here in great perfection and at a very cheap rate.

16. *The Mint* is kept up by the articles of Union, with all the offices belonging to it, though no money is ever ſtruck here. It ſtands in the Cowgate, a little to the weſt of the Engliſh church; but is in a ruinous ſtate, though ſtill inhabited by the different officers, who have free houſes: and the bellman enjoys his ſalary by regularly ringing the bell. This place, as well as the abbey of Holyroodhouſe, is an aſylum for debtors.

17. *The Engliſh Chapel* ſtands near the Cowgate Port, and was founded on the 3d of April 1771. The foundation ſtone was laid by General Oughton, with the following inſcription: *Edificii ſacr. Eccleſiæ epiſc. Angliæ, primum poſuit lapidem J. Adolphus Oughton, in architectonicæ Scotiæ repub. curio maximus, militum præfectus, regnante Georgio* III. *tertio Ap. die, A. D.* MDCCLXXI. It is a plain handſome building, neatly fitted up in the inſide, and ſomewhat reſembling the church of St Martin's in the Fields, London. It is 90 feet long, 75 broad, and ornamented with an elegant ſpire of conſiderable height. It is alſo furniſhed with an excellent bell, formerly belonging to the chapel royal at Holyroodhouſe, which is permitted to be rung for aſſembling the congregation; an indulgence not granted to the Preſbyterians in England. The expence of the building was defrayed by voluntary ſubſcription; and to the honour of the country, people of all perſuaſions contributed to this pious work. It has already coſt 7000l. and will require 1000l. more to finiſh the portico. This church is built in a ſingular manner, viz. from ſouth to north, and the altar-piece ſtands on the eaſt ſide. Three clergymen officiate here, of whom the firſt has 150l. the other two 100l. each: the altar-piece is finely decorated, and there is a good organ.

There is another Epiſcopal chapel, but ſmall, in Blackfriars wynd, which was founded by Baron Smith in the year 1722. There are alſo ſome meetings of the Epiſcopal church of Scotland, who adhere to their old forms, having ſtill their biſhops and inferior clergy. For ſome time theſe were ſubjected to penal laws, as they refuſed to take the oath to government, or mention the preſent royal family in their public prayers: but having conformed, and taken the oath of allegiance, their conduct has been approved of by his majeſty; ſo that now every denomination of Chriſtians in Britain pray for the royal family on the throne.

18. *Heriots Hoſpital* owes its foundation to George Heriot, goldſmith to James VI. who acquired by his buſineſs a large fortune. At his death, he left the magiſtrates of Edinburgh 23,625l. 10s. "for the maintenance, relief, and bringing up of ſo many poor and fatherleſs boys, freemen's ſons of the town of Edinburgh," as the above ſum ſhould be ſufficient for. This hoſpital is finely ſituated on the weſt end of the ſouth ridge, almoſt oppoſite to the caſtle, and is the moſt magnificent building of the kind in Edinburgh. It was founded in July 1628, according to a plan (as is reported) of Inigo Jones; but the work being interrupted by the civil wars, it was not finiſhed till the year 1650. The expence of the building is ſaid to have been upwards of 30,000l. (A): and the hoſpital is now poſſeſſed of an income of about 3000l. a-year; though this cannot be abſolutely aſcertained, as the rents are paid in grain, and of courſe muſt be fluctuating.

It ſtands on a riſing ground to the ſouth-weſt of the city, and is a ſquare of 162 feet without, having a court 94 feet ſquare in the inſide, with piazzas on three of the ſides. There is a ſpire with a clock over the gateway, and each corner of the building is ornamented with turrets; but notwithſtanding the magnificent appearance of the outſide, the inner part is far from being convenient. There is a ſtatue of the founder over the gateway, in the dreſs of the times, and a very good painting of him in the governors room, with a picture of the late treaſurer Mr Carmichael. There is a chapel 61 feet long and 22 broad, which is now repairing in ſuch a manner as will make it worthy of notice. When Cromwell took poſſeſſion of Edinburgh after the battle of Dunbar, he quartered his ſick and wounded ſoldiers in this hoſpital. It was applied to the ſame purpoſe till the year 1658, when General Monk, at the requeſt of the governors, removed the ſoldiers; and on the 11th of April 1659, it was opened for the reception of boys, 30 of whom were admitted into it. The Auguſt after, they were increaſed to 40; and in 1661, to 52. In 1753 the number was raiſed to 130, and in 1763 to 140; but ſince that time it has decreaſed.—In this hoſpital the boys are inſtructed in reading, writing, arithmetic, and a knowledge of the Latin tongue. With ſuch as chooſe to follow any kind of trade, an apprentice fee of 30l. is given when they leave the hoſpital; and thoſe who chooſe an academical education, have an annuity of 10l. a-year beſtowed on them for four years. The whole is under the overſight of the treaſurer, who has under him a houſe governor, houſekeeper, and ſchoolmaſters.

(A) It is to be obſerved, that money then bore 10l. per cent. intereſt.—The above ſums are taken from Mr Arnot's Hiſtory of Edinburgh, who ſubjoins the following note. "Where Maitland had collected his moſt erroneous account of George Heriot's effects we do not know. He makes the ſum received, out of Heriot's effects, by the governors of the hoſpital, to be 43,608l. 11s. 3d. being almoſt double of what they really got. This blunder has been the cauſe of many unjuſt murmurings againſt the magiſtrates of Edinburgh, and even the means of ſpiriting up lawſuits againſt them."

19. *Watſon's Hoſpital* has its name from the founder George Watſon, who was at firſt clerk to Sir William Dick provoſt of Edinburgh in 1676, then accountant of the bank of Scotland; after that he became receiver of the city's impoſt on ale, treaſurer to the Merchants Maiden Hoſpital, and to the ſociety for propagating Chriſtian knowledge. Dying a bachelor in 1723, he left 12,000l. for the maintenance and education of the children and grandchildren of decayed members of the merchant company of Edinburgh. The ſcheme, however, was not put in execution till the year 1738, when the ſum originally left had accumulated to 20,000l. The preſent building was then erected, in which about 60 boys are maintained and educated. It is much leſs magnificent then Heriot's hoſpital, but the building is far from being deſpicable. It ſtands to the ſouthward of the city at a ſmall diſtance from Heriot's hoſpital, and was erected at the expence of 5000l.: its preſent revenue is about 1700l. It is under the management of the maſter, aſſiſtants, and treaſurer of the Merchant Company, four old bailies, the old dean of guild, and the two miniſters of the Old church. The boys are genteelly clothed and liberally educated. Such as chooſe an univerſity education are allowed 10l. per annum for five years: thoſe who go to trades have 20l. allowed them for their apprentice fee, and at the age of 25 years, if they have behaved properly, and not contracted marriage without conſent of the governors, they receive a bounty of 50l. The boys are under the immediate inſpection of the treaſurer, ſchoolmaſter, and houſekeeper.

20. *The Merchants Maiden Hoſpital* was eſtabliſhed by voluntary contribution about the end of the laſt century, for the maintenance of young girls, daughters of the merchants burgeſſes of Edinburgh. The governors were erected into a body corporate, by act of parliament, in 1707. The annual revenue amounts to 1350l. Seventy girls are maintained in it; who, upon leaving the houſe, receive 3l. 6s. 8d. excepting a few who are allowed 8l. 6s. 8d. out of the funds of the hoſpital. The profits ariſing from work done in the houſe are alſo divided among the girls, according to their induſtry.

21. *The Trades Maiden Hoſpital* was founded in the year 1704 by the incorporations of Edinburgh, for the maintenance of the daughters of decayed members, on a plan ſimilar to that of the merchants hoſpital. To this, as well as to the former, one Mrs Mary Erſkine, a widow gentlewoman, contributed ſo liberally, that ſhe was by the governors ſtyled *joint foundreſs* of the hoſpital. Fifty girls are maintained in the houſe, who pay of entry money 1l. 13s 4d.; and, when they leave it, receive a bounty of 5l. 11s. 1½d. The revenues are eſtimated at 600l. a-year.

22. *The Orphan Hoſpital* was planned in 1732, by Andrew Gairdner merchant, and other inhabitants. It was promoted by the ſociety for propagating Chriſtian knowledge, by other ſocieties, by voluntary ſubſcriptions, and a collection at the church doors.—In 1733, the managers hired a houſe, took in 30 orphans, maintained them, gave them inſtructions in reading and writing, and taught them the weaving buſineſs. In 1735, they were erected into a body corporate by the town of Edinburgh: and, in 1742, they obtained a charter of erection from his late majeſty, appointing moſt of the great officers of ſtate in Scotland, and the heads of the different ſocieties in Edinburgh, members of this corporation; with powers to them to hold real property to the amount of 1000l. a-year. The revenue is inconſiderable; but the inſtitution is ſupported by the contributions of charitable perſons. Into this hoſpital orphans are received from any part of the kingdom. None are admitted under ſeven, nor continued in it after 14 years of age.

The orphan hoſpital is ſituated to the eaſt of the North bridge; and is a handſome building, conſiſting of a body and two wings, with a neat ſpire, furniſhed with a clock and two bells. The late worthy Mr Howard admits, that this inſtitution is one of the moſt uſeful charities in Europe, and is a pattern for all inſtitutions of the kind. The funds have been conſiderably increaſed, and the building greatly improved, through the attention and exertions of Mr Thomas Tod formerly treaſurer.

23. *The Trinity Hoſpital.* This was originally founded and amply endowed by King James II.'s queen. At the Reformation, it was ſtripped of its revenues; but the regent afterwards beſtowed them on the provoſt of Edinburgh, who gave them to the citizens for the uſe of the poor. In 1585, the town council purchaſed from Robert Pont, at that time provoſt of Trinity college, his intereſt in theſe ſubjects; and the tranſaction was afterwards ratified by James VI. The hoſpital was then repaired, and appointed for the reception of poor old burgeſſes, their wives and unmarried children, not under 50 years of age. In the year 1700, this hoſpital maintained 54 perſons; but, ſince that time, the number has decreaſed.—The revenue conſiſts in a real eſtate of lands and houſes, the groſs rents of which are 762l. a year, and 5500l. lent out in bonds at 4 per cent.

This hoſpital is ſituated at the foot of Leith wynd, and maintains about 50 of both ſexes, who are comfortably lodged, each having a room for themſelves. They are ſupplied with roaſt or boiled meat every day for dinner, have money allowed them for clothes, and likewiſe a ſmall ſum for pocket money. There is a ſmall library for their amuſement, and they have a chaplain to ſay prayers. There are ſome out-penſioners who have 6l. a-year, but theſe are diſcouraged by the governors. The funds are under the management of the town council.

24. *The Charity Workhouſe* was erected in 1743 by voluntary contribution. It is a large plain building, on the ſouth ſide of the city. Here the poor are employed, and are allowed twopence out of every ſhilling they earn. The expence of this inſtitution is ſuppoſed not to be leſs than 4000l. annually; as about 700 perſons of both ſexes, including children, are maintained here, each of whom cannot be reckoned to coſt leſs than 4l. 10s. per annum; and there are beſides 300 out-penſioners. The only permanent fund for defraying this expence is a tax of two per cent. on the valued rents of the city, which may bring in about 600l. annually; and there are other funds which yield about 400l. The reſt is derived from collections at the church doors and voluntary contributions; but as theſe always fall ſhort of what is requiſite, recourſe muſt frequently be had to extraordinary collections. The ſum ariſing from the rents of the city, however, is

conſtantly

conſtantly increaſing; but the members of the college of juſtice are exempted from the tax.

25. "To the ſouth-weſt of the caſtle, near a ſuburb called the *Wrights Houſes*, on the ſite of a very ancient building, which was demoliſhed to make way for it, *Gilleſpie's Hoſpital* has lately been erected. Its appellation is derived from the founder, an eminent manufacturer of ſnuff in Edinburgh. It is intended for the ſupport of aged perſons; and thoſe bearing the name of the founder are preferred. It is a neat ſtone building, executed in a ſtyle of moderate expence, with a ſmall tower in the centre and a parapet, and Gothic turrets at ſuitable diſtances around the roof.

"Beſides theſe there are to be found in Edinburgh ſeveral charitable eſtabliſhments, which, though not furniſhed with coſtly buildings, are not of a leſs benevolent or valuable nature. Of theſe, one of the moſt diſtinguiſhed is the Hoſpital or Workhouſe, or *Aſylum*, as it is called, *for the Induſtrious Blind;* which is ſupported by the contributions of charitable perſons, and by the price of the articles manufactured in it. Here the blind are taught ſuch trades as may enable them to earn a ſubſiſtence, or at leaſt aid them in contributing to their own ſupport. They manufacture baſkets, matts, &c.; and ſome of them have been taught to act as weavers, for which purpoſe they uſe the fly-ſhuttle.

"The *Magdalene Aſylum* alſo deſerves notice; in which a moſt laudable attempt has of late years been made, by a benevolent ſociety, to reclaim, from vice and miſery, women who have degraded themſelves by public proſtitution, but who think fit to retire thither with the view of abandoning their mode of life, and of ſupporting themſelves by induſtry. This inſtitution is managed with a degree of care and delicacy which does the higheſt credit to its patrons. The objects of this charity are kept concealed: they reap the fruits of their own labour; and every effort is made to procure employment for them. In particular, needle-work of all ſorts is executed in it in the neateſt manner; and linen is waſhed, at moderate prices, for ſuch perſons in the city as think fit to tranſmit theſe articles to the ſociety.

"Beſides all theſe charities, there is an hoſpital in the city for *Lying-in Women*, under the care of the profeſſor of midwifery: which is an inſtitution analagous to that of the Royal Infirmary.—There is a *Society for the Relief of the Deſtitute Sick*, which has received conſiderable public countenance, though it has no appropriate building or local eſtabliſhment.—An inſtitution of a peculiar nature, not unconnected with the preſent ſubject, called the *Repoſitory*, ought not to paſs unnoticed. It is a ſhop or ware-room on South Bridge Street, to which ladies in ſtraitened circumſtances have an opportunity of ſending for ſale curious, beautiful, or uſeful articles of needle-work, with the price affixed. When a purchaſer has been found for the goods, the proceeds are tranſmitted in ſuch a manner as to prevent its being known to the public by whom the articles were prepared. This inſtitution has been promoted by the Ducheſs of Buccleugh and many other perſons of rank."

Beauties of Scotland, I. 69.

There are two other charity workhouſes in the ſuburbs, much on the ſame plan with that now deſcribed: one in the Canongate, and the other in St Cuthbert's or Weſt kirk pariſh.

To this account of the charitable eſtabliſhments in Edinburgh, we ſhall add that of ſome others; which, though not calculated to decorate the city by any public building, are perhaps no leſs deſerving of praiſe than any we have mentioned. The firſt is that of Captain William Horn; who left 3500l. in truſt to the magiſtrates, the annual profits to be divided on Chriſtmas day to poor out-day labourers, who muſt at that ſeaſon of the year be deſtitute of employment; five pounds to be given to thoſe who have large families, and one half to thoſe who have ſmaller.

Another charity is that of Robert Johnſton, LL. D. of London, who in 1640 left 3000l. to the poor of this city; 1000l. to be employed in ſetting them to work, another 1000l. to clothe the boys in Heriot's Hoſpital, and the third 1000l. to burſars at the univerſity.

About the beginning of this century John Strachan left his eſtate of Craigcrook, now upwards of 300l. a-year, in truſt to the preſbytery of Edinburgh, to be by them diſpoſed of in ſmall annual ſums to poor old people not under 65 years of age, and to orphans not above 12.

There is beſides a ſociety for the ſupport of the induſtrious poor, another for the indigent ſick, and there are alſo many charity ſchools.

Having thus given an account of the moſt remarkable edifices belonging to Old Edinburgh, we ſhall now proceed to thoſe of the New Town. This is terminated on the eaſt ſide by the Calton hill, round which there is a pleaſant walk, and which affords one of the fineſt proſpects that can be imagined, varying remarkably almoſt at every ſtep. On this hill is a burying ground, which contains a fine monument to the memory of David Hume the hiſtorian.—On the top is an obſervatory, the ſcheme for building which was firſt adopted in the year 1736; but the diſturbance occaſioned by the Porteous mob prevented any thing from being done towards the execution of it at that time. The earl of Morton afterwards gave 100l. for the purpoſe of building an obſervatory, and appointed Mr M'Laurin profeſſor of mathematics, together with the principal and ſome profeſſors of the univerſity, truſtees for managing the ſum. Mr M'Laurin added to the money above mentioned the profits ariſing from a courſe of lectures which he read on experimental philoſophy; which, with ſome other ſmall ſums, amounted in all to 300l.; but Mr M'Laurin dying, the deſign was dropped.—Afterwards the money was put into the hands of two perſons who became bankrupt; but a conſiderable dividend being obtained out of their effects, the principal and intereſt, about the year 1776, amounted to 400l. A plan of the building was made out by Mr Craig architect; and the foundation ſtone was laid by Mr Stodart, lord provoſt of Edinburgh, on the 25th of Auguſt 1776. About this time, however, Mr Adam architect happening to come to Edinburgh, conceived the idea of giving the whole the appearance of a fortification, for which its ſituation on the top of the Calton hill was very much adapted. Accordingly a line was marked out for encloſing the limits of the obſervatory with a wall conſtructed

ſtructed with buttreſſes and embraſures, and having Gothic towers at the angles. Thus the money deſigned for the work was totally exhauſted, and the obſervatory ſtill remains unfiniſhed; nor is there any appearance of its being ſoon completed either by voluntary ſubſcription or any other way.

26. Proceeding to the weſtward, the firſt remarkable building is the *Theatre*, which ſtands oppoſite to the Regiſter Office, in the middle of Shakeſpeare Square. The building is plain on the outſide, but elegantly fitted up within, and is generally open three days in the week, and when full will draw about 150l. a-night; ſo that the manager generally finds himſelf well rewarded when he can procure good actors.

Entertainments of the dramatic kind came very early into faſhion in this country. They were at firſt only repreſentations of religious ſubjects, and peculiarly deſigned to advance the intereſts of religion; the clergy being the compoſers, and Sunday the principal time of exhibition. In the 16th century, the number of playhouſes was ſo great, that it was complained of as a nuiſance, not only in Edinburgh, but throughout the kingdom. They ſoon degenerated from their original inſtitution; and the plays, inſtead of being calculated to inſpire devotion, became filled with all manner of buffoonery and indecency.—After the Reformation, the Preſbyterian clergy complained of theſe indecencies; and being actuated by a ſpirit of violent zeal, anathematized every kind of theatrical repreſentation whatever. King James VI. compelled them to paſs from their cenſures againſt the ſtage; but in the time of Charles I. when fanaticiſm was carried to the utmoſt length at which perhaps it was poſſible for it to arrive, it cannot be ſuppoſed that ſtage plays would be tolerated.—It ſeems, however, that amuſements of this kind were again introduced at Edinburgh about the year 1684, when the duke of York kept his court there. His reſidence at Edinburgh drew off one half of the London company, and plays were acted in Edinburgh for ſome little time. The misfortunes attending the duke of York, however, and the eſtabliſhment of the Preſbyterian religion (the genius of which is unfavourable to amuſements of this kind), ſoon put a ſtop to the progreſs of the ſtage, and no theatrical exhibition was heard of in Edinburgh till after the year 1715. The firſt adventurer was Signora Violante, an Italian, remarkable for feats of ſtrength, tumbling, &c. In this way ſhe firſt exhibited in a houſe at the foot of Carubber's cloſe, which has ſince been employed by different ſectaries for religious purpoſes. Meeting with good ſucceſs, ſhe ſoon invited a company of comedians from London; and theſe being alſo well received, Edinburgh continued for ſome years to be entertained with the performances of a ſtrolling company, who viſited it annually. Becoming at laſt, however obnoxious to the clergy, they were in 1727 prohibited by the magiſtrates from acting within their juriſdiction. But this interdict was ſuſpended by the court of ſeſſion, and the players continued to perform as uſual.

Still, however, theatrical entertainments were but rare. The town was viſited by itinerant companies only once in two or three years. They performed in the Taylor's Hall in the Cowgate; which, when the houſe was full, would have drawn (at the rate of 2s. 6d. for pit and boxes, and 1s. 6d. for the gallery) 40l. or 45l. a night. About this time an act of parliament was paſſed, prohibiting the exhibition of plays, except in a houſe licenſed by the king. Of this the preſbytery of Edinburgh immediately laid hold; and at their own expence brought an action on the ſtatute againſt the players. The cauſe was by the court of ſeſſion decided againſt the players; who thereupon applied to parliament for a bill to enable his majeſty to licenſe a theatre in Edinburgh. Againſt this bill petitions were preſented in 1739 to the houſe of commons by the magiſtrates and town council, the principal and profeſſors of the univerſity, and the dean of guild and his council; in conſequence of which, the affair was dropped. All this oppoſition, however, contributed in reality to the ſucceſs of the players; for the ſpirit of party being excited, a way of evading the act was eaſily found out, and the houſe was frequented more than uſual, inſomuch that Taylor's Hall was found inſufficient to contain the number of ſpectators.

The comedians now fell out among themſelves, and a new playhouſe was erected in the Canongate in the year 1746. The conſequence of this was, that the old one in Taylor's Hall became entirely deſerted, and through bad conduct the managers of the new theatre ſoon found themſelves greatly involved. At laſt, a riot enſuing through diſſenſions among the performers, the playhouſe was totally demoliſhed.—When the extenſion of the royalty over the ſpot where the New Town is built was obtained, a clauſe was likewiſe added to the bill, enabling his majeſty to licenſe a theatre in Edinburgh. This was obtained, and thus the oppoſition of the clergy for ever ſilenced. But notwithſtanding this, the high price paid by the managers to the patentee, being no leſs than 500 guineas annually, prevented them effectually from decorating the houſe as they would otherwiſe have done, or even from always retaining good actors in their ſervice; by which means the ſucceſs of the Edinburgh theatre has not been ſo great as might have been expected.

Not far from this building, an amphitheatre was opened in 1790, on the road to Leith, for equeſtrian exhibitions, pantomine entertainments, dancing, and tumbling. The circus was 60 feet diameter; and in the forenoon ladies and gentlemen were taught to ride. The houſe held about 1500 people. This building has been ſince converted into an elegant and commodious concert room.

27. *The Regiſter Office.* This work was firſt ſuggeſted by the late Earl of Morton, lord-regiſter of Scotland, with a view to prevent the danger which attended the uſual method of keeping the public records. In former times, indeed, theſe ſuffered from a variety of accidents. Edward I. carried off or deſtroyed moſt of them, in order to prevent any marks of the former independence of the nation from remaining to poſterity. Afterwards Cromwell ſpoiled this nation of its records, moſt of which were ſent to the Tower of London. At the time of the reſtoration, many of them were ſent down again by ſea; but one of the veſſels was ſhipwrecked, and the records brought by the other have ever ſince been left in the greateſt confuſion.—The Earl of Morton taking this into conſideration, obtained from his majeſty a grant of 12,000l. out of the forfeited eſtates, for the purpoſe of building a regiſter office,

office, or houſe for keeping the records, and diſpoſing them in proper order. The foundation was laid on the 27th of June 1774, by Lord Frederic Campbell lord-regiſter, Mr Montgomery of Stanhope lord advocate, and Mr Miller of Barſkimming lord juſtice clerk; three of the truſtees appointed by his majeſty for executing the work. The ceremony was performed under a diſcharge of artillery, in preſence of the judges of the courts of ſeſſion and exchequer, and in the ſight of a multitude of ſpectators. A braſs plate was put into the foundation ſtone with the following inſcription: CONSERVANDIS TABULIS PUBLICIS POSITUM EST, ANNO M.DCC.LXXIV, MUNIFICENTIA OPTIMI ET PIETISSIMI PRINCIPIS GEORGII TERTII. In a glaſs vaſe hermetically ſealed, which is alſo placed in the foundation ſtone, are depoſited ſpecimens of the different coins of his preſent majeſty.

The front of the building directly faces the bridge, extends from eaſt to weſt 100 feet, and is 40 feet back from the line of Prince's ſtreet. In the middle of the front is a ſmall projection of three windows in breadth. Here is a pediment, having in its centre the arms of Great Britain, and the whole is ſupported by four Corinthian pilaſters. At each end is a tower projecting beyond the reſt of the building, having a Venetian window in front, and a cupola on the top. The front is ornamented from end to end with a beautiful Corinthian entablature. In the centre of the building is a dome of wooden work covered with lead. The inſide forms a ſaloon 50 feet diameter and 80 high, lighted at top by a copper window 15 feet in diameter. Round the whole is a hanging gallery of ſtone, with an iron balluſtrade, which affords conveniency for preſſes in the walls for keeping the records. The whole number of apartments is 97; all of which are vaulted beneath, and warmed with fire-places. This building, which is the moſt beautiful of Mr Adam's deſigns, has been executed in a ſubſtantial manner, in about 16 years, at the expence of near 40,000l. and is one of the principal ornaments of the city. A ſerjeant's guard is placed here from the caſtle, for the further protection of the records. It is intended to place a ſtatue of his preſent majeſty in the front of the building, with the lion and unicorn above the centinels boxes. The lord-regiſter has the direction of the whole, and the principal clerks of ſeſſion are his deputes. Theſe have a great number of clerks under them for carrying on the buſineſs of the court of ſeſſion. The lord-regiſter is a miniſter of ſtate in this country. He formerly collected the votes of the parliament of Scotland, and ſtill collects thoſe of the peers at the election of 16 to repreſent them in parliament.

27. On the eaſt ſide of St. Andrew's ſquare ſtands the *General Exciſe Office*, built by the late Sir Lawrence Dundas for his own reſidence, but ſold by his ſon for the above purpoſe. It is a very handſome building, with a pediment in front ornamented with the king's arms, and ſupported by four Corinthian pilaſters; and, in conjunction with the two corner houſes, has a fine effect.

28. *St Andrew's Church* ſtands on the north ſide of George's ſtreet, It is of an oval form; and has a very neat ſpire of 186 feet in height, with a chime of eight bells, the firſt and only one of the kind in Scotland. It has alſo a handſome portico in front.

29. Oppoſite to St Andrew's church is the *Phyſicians Hall*, deſigned for the meetings of the faculty, and which has a portico reſembling that of the church.

30. Farther to the weſtward, on the ſouth ſide, ſtand the *Aſſembly Rooms*, which though a heavy looking building on the outſide, are nevertheleſs extremely elegant and commodious within. The largeſt is 100 feet long and 40 broad, being exceeded in its dimenſions by none in the iſland, the large one at Bath excepted. Weekly aſſemblies are held here for dancing and card-playing, under the direction of a maſter of ceremonies; admiſſion tickets five ſhillings each.

"There are three Banking Companies in Edinburgh eſtabliſhed by ſtatute, or by royal charters. Theſe are, the Bank of Scotland, commonly called the Old Bank, the Royal Bank of Scotland, and the Britiſh Linen Company.

31. "The *Bank of Scotland*, commonly called the *Old Bank*, was erected by act of parliament, A. D. 1695. By the ſtatute of erection, the company was empowered to raiſe a joint ſtock of 1,200,000l. Scots, or 100,000l. Sterling, for the purpoſe of carrying on a public bank. The ſmalleſt ſhare which any perſon could hold in the bank was declared to be 1000l. Scots; and the largeſt ſum for which any one was allowed to ſubſcribe was 20,000l. of the ſame money. Eight thouſand are declared to be the qualification neceſſary to entitle any one to be elected governor; 6000l. deputy governor; and 3000l. for each director. The management of the affairs of the company was veſted in a governor, deputy governor, and twenty-four directors; and in chooſing theſe managers, each proprietor was declared to have a vote for every 1000l. of ſtock held by him.

"The office of this company has hitherto been held in a houſe down a narrow lane at the ſouth ſide of that part of the High ſtreet called the Lawn-market; but, at a great expence, they have erected for their accommodation a building which will ſpeedily be ready to be occupied, and which is ſituated to the northward of the High ſtreet, in full view of Prince's ſtreet. This is at once a magnificent and beautiful fabric. The back of the building is towards Prince's ſtreet; and here, while erecting, it had the diſadvantage, from its vaſt height, of having ſomewhat the aſpect of a tower. This effect, however, is now removed by reſtoring the earth for the purpoſe of covering up the lower part of it, and by a wall of conſiderable height in the nature of a curtain, which has been added to augment its apparent breadth. It forms, upon the whole, a beautiful and moſt ſuperb fabric. As a work of magnitude, it is ſeen to moſt advantage from the mound of earth which connects the Old and the New Town, at that part of the mound which is in the direction of the north-weſt angle of the building. Here the eye is filled by the full view of two ſides of the fabric, and by a diſplay of its great height. The reſult of which is, that as a magnificent and ſtupendous ſtructure, it ſeems to have no rival in this country.

"This banking company has eſtabliſhed branches in every conſiderable town in Scotland, excepting Glaſgow, which, in conſequence of an amicable adjuſtment to avoid rivalſhip, is left to the Royal Bank. By agreement, the latter has a branch at Glaſgow, and no branch in any other town in Scotland.

33. " The *Royal Bank* was eſtabliſhed in the following manner: By the articles of union, Scotland was declared to be liable to the ſame duties which were levied by way of cuſtoms or exciſe in England. As theſe duties had, in the latter of theſe nations, been appropriated for the diſcharge of debts contracted by England before the union, it was found reaſonable to give Scotland an equivalent for this additional burthen. The ſum, given by way of equivalent, was ordained to be paid for certain purpoſes, and to certain perſons or bodies corporate, mentioned in the articles of union and in poſterior ſtatutes. The proprietors of theſe ſums, to the extent of 248,550l. Sterling, were erected into a body corporate, under the name of the *Equivalent Company*; and the ſaid ſum of 248,550l. was declared to be the joint ſtock of the company. Upon application by this company, they obtained a royal charter, empowering ſuch of them as inclined to ſubſcribe their ſhares in the joint ſtock for that purpoſe, to carry on the buſineſs of banking. By this charter the ſubſcribers to this banking buſineſs were, in A. D. 1727, erected into a body corporate, to be called, " *The Royal Bank of Scotland*." They were veſted with the requiſite powers, and the management of the company's affairs declared to be in a governor, deputy governor, nine ordinary and nine extraordinary directors. The qualifications of theſe managers were declared to be, that of the governor to hold ſtock to the extent of 2000l.; of the deputy governor, of 1500l.; of the ordinary directors, of 1000l.; and of the extraordinary directors, of 500l. The ſum originally ſubſcribed was 111,000l.; but by a charter paſſed in favour of the Royal Bank, A. D. 1738, explaining the privileges formerly beſtowed upon them, and enabling them to increaſe their capital, they were empowered to raiſe their ſtock to a ſum not exceeding in whole, when joined to their original funds, 150,000l. By the charter of erection of this company, a ſhare of 300l. entitles a proprietor to one vote, one of 600l. to two, of 1200l. to three, and of 2000l. to four; and no proprietor can have more than four votes.

34. " The *Britiſh Linen Company*, with a capital of 100,000l. was incorporated by royal charter in 1746, with a view to encourage the manufacture of linen in Scotland. By the conſtitution of this company, its affairs are declared to be under the management of a governor, deputy governor, and five directors. It is declared a neceſſary qualification in the governor to be poſſeſſed of a ſhare in the company's ſtock to the amount of 1000l.; of the deputy governor, 500l.; and of each director, of 300l. A ſhare of 200l. entitles a proprietor to vote in the choice of theſe managers, of 500l. to two votes, and of 1000l. to four votes; but it is declared that no proprietor ſhall poſſeſs more than four votes.

" This company carries on the buſineſs of banking, and iſſues promiſſory notes like the two former companies; but the banking buſineſs is carried on ſeparately from the linen trade. The Linen Hall remains in the Canongate; but the apartments of the bank are removed to a lane on the ſouth ſide of the High ſtreet, above what was called the Nether-bow port.

" Promiſſory notes, payable on demand, have alſo been long iſſued in Edinburgh by a private banking houſe, that of Sir William Forbes, Sir James Hunter, and Company; and their notes have poſſeſſed a moſt extenſive circulation.

" Beſides theſe there are ſeveral private banking houſes of great reputation in Edinburgh, which do not iſſue promiſſory notes for ſmall ſums payable on demand, but which carry on the other branches of the banking trade, by tranſmitting money, diſcounting bills, and accommodating individuals with caſh accounts."

Beauties of Scotland, I. 91.

29
Religious eſtabliſhments.

It now remains only to ſpeak ſomething of the religious and civil eſtabliſhments of this metropolis. The higheſt of the former is the General Aſſembly of the Church of Scotland, who meet here annually in the month of May, in an aiſle of the church of St Giles fitted up on purpoſe for them. The throne is filled by a commiſſioner from his majeſty, but he neither debates nor votes. He calls them together, and diſſolves them at the appointed time in the name of the king; but they call and diſſolve themſelves in the name of the Lord Jeſus Chriſt. This aſſembly conſiſts of 350 members choſen out of the various preſbyteries throughout the kingdom; and the debates are often very intereſting and eloquent. This is the ſupreme eccleſiaſtical court in Scotland, to which appeals lie from the inferior ones.

The eccleſiaſtical court next in dignity to the aſſembly is the Synod of Lothian and Tweeddale, who meet in the ſame place in April and November; and next to them is the Preſbytery of Edinburgh. Theſe meet on the laſt Wedneſday of every month, and are truſtees on the fund for miniſters widows. They have a hall in Scott's cloſe, where there is a good picture of Dr Webſter by Martin, which was put up at the expence of the truſtees, out of gratitude for the trouble he took in planning and fully eſtabliſhing the fund.

The Society for propagating Chriſtian Knowledge in the Highlands and Iſlands of Scotland, was eſtabliſhed a body corporate by Queen Anne in the year 1709, for the purpoſe of erecting ſchools to inſtruct poor children in the principles of Chriſtianity, as well as in reading and writing. The ſociety have a hall in Warriſton's cloſe where their buſineſs is tranſacted. From time to time they have received large contributions, which have always been very properly applied; and for much the ſame purpoſe his majeſty gives 1000l. annually to the general aſſembly of the church of Scotland, which is employed by a committee of their number for inſtructing the poor Highlanders in the principles of the Chriſtian religion.

The Erſe church at Edinburgh was built about 30 years ago by ſubſcriptions for the ſame laudable purpoſe. Great numbers of people reſort to the metropolis from the Highlands, who underſtand no other language but their own, and conſequently have no opportunity of inſtruction without it; and a moſt remarkable proof of the benefit they have received from it is, that though the church is capable of holding 1000 people, yet it is not large enough for thoſe who apply for ſeats. The miniſter has 100l. per annum ariſing from the ſeat rents, and holds communion with the church of Scotland. The eſtabliſhment was promoted by William Dickſon dyer in Edinburgh.

30
Political conſtitution.

With regard to the political conſtitution of Edinburgh, the town council have the direction of all public affairs. The *ordinary* council conſiſts only of 25 perſons; but the *council ordinary and extraordinary*, of 33. The whole is compoſed of merchants and tradeſmen, whoſe reſpective powers and intereſts are ſo interwoven, that a balance is preſerved between the two bodies. The members of the town council are partly elected by the members of the 14 incorporations, and they partly chooſe their own ſucceſſors. The election is made in the following manner: Firſt, a liſt or *leet* of ſix perſons is made out by each incorporation; from which number, the deacon belonging to the incorporation muſt be choſen. Theſe liſts are then laid before the ordinary council of 25, who "ſhorten the *leets*," by expunging one half of the names from each; and from the three remaining ones the deacon is to be choſen. When this election is over, the new deacons are preſented to the ordinary council, who chooſe ſix of them to be members of their body, and the ſix deacons of laſt year then walk off. The council of 25 next proceed to the election of three merchant and two trades counſellors. The members of council, who now amount to 33 in number, then make out *leets*, from which the lord provoſt, dean of guild, treaſurer, and bailies, muſt be choſen. The candidates for each of theſe offices are three in number; and the election is made by the 30 members of council already mentioned, joined to the eight *extraordinary* council deacons.

The lord provoſt of Edinburgh, who is ſtyled *right honourable*, is high ſheriff, coroner, and admiral, within the city and liberties, and the town, harbour, and road of Leith. He has alſo a juriſdiction in matters of life and death. He is preſes of the convention of royal boroughs, colonel of the trained bands, commander of the city guard and of Edinburgh jail. In the city he has the precedency of all the great officers of ſtate and of the nobility; walking on the right hand of the king or of his majeſty's commiſſioner; and has the privilege of having a ſword and mace carried before him. Under him are four magiſtrates called *bailies*, whoſe office is much the ſame with that of aldermen in London. There is alſo a dean of guild, who has the charge of the public buildings, and without whoſe warrant no houſe nor building can be erected within the city. He has a council to conſult with, a nominal treaſurer, who formerly had the keeping of the town's money, which is now given to the chamberlain. Theſe ſeven are elected annually; who with the ſeven of the former year, three merchants and two trades counſellors, and 14 deacons or preſes of incorporated trades, making in all 33, form the council of the city, and have the ſole management and diſpoſal of the city revenues; by which means they have the diſpoſal of places to the amount of 20,000l. annually. Formerly the provoſt was alſo an officer in the Scots parliament. The magiſtrates are ſheriffs-depute and juſtices of the peace; and the town council are alſo patrons for all the churches in Edinburgh, patrons of the univerſity, and electors of the city's repreſentative in parliament. They have beſides a very ample juriſdiction both civil and criminal. They are ſuperiors of the Canongate, Portſburgh, and Leith; and appoint over theſe certain of their own number, who are called *baron bailies*: but the perſon who preſides over Leith has the title of *admiral* becauſe he hath there a juriſdiction over maritime affairs. The baron bailies appoint one or two of the inhabitants of their reſpective diſtricts to be their ſubſtitutes, and theſe are called *reſident bailies*. They hold courts in abſence of the baron bailies, for petty offences and diſcuſſing civil cauſes of little moment.

31 Town guard.

No city in the world affords greater ſecurity to the inhabitants in their perſons and properties than Edinburgh. Robberies are here very rare, and ſtreet murder hardly known in the memory of man; ſo that a perſon may walk the ſtreets at any hour of the night in perfect ſecurity. This is in a great meaſure owing to the *town guard*. This inſtitution originated from the conſternation into which the citizens were thrown after the battle at Flowden. At that time, the town council commanded the inhabitants to aſſemble in defence of the city, and every fourth man to be on duty each night. This introduced a kind of perſonal duty for the defence of the town, called *watching and warding*; by which the trading part of the inhabitants were obliged in perſon to watch alternately, in order to prevent or ſuppreſs occaſional diſturbances. This, however, becoming in time extremely inconvenient, the town council, in 1648, appointed a body of 60 men to be raiſed; the captain of which was to have a monthly pay of 11l. 2s. 3d. two lieutenants of 2l. each, two ſerjeants of 1l. 5s. and the private men of 15s. each. No regular fund was eſtabliſhed for defraying this expence: the conſequence of which was, that the old method of watching and warding was reſumed; but the people on whom this ſervice devolved were now become ſo relaxed in their diſcipline, that the magiſtrates were threatened with having the king's troops quartered in the city if they did not appoint a ſufficient guard. On this 40 men were raiſed in 1679, and in 1682 the number was increaſed to 108. After the Revolution, the town council complained of the guard as a grievance, and requeſted parliament that it might be removed. Their requeſt was immediately granted, and the old method of watching and warding was renewed. This, however, was now ſo intolerable, that the very next year they applied to parliament for leave to raiſe 126 men for the defence of the city, and to tax the citizens for their payment. This being granted, the corps was raiſed which ſtill continues under the name of the *town guard*. At preſent the eſtabliſhment conſiſts of three officers and about 90 men, who mount guard by turns. The officers have a lieutenant's pay; the ſerjeants, corporals, drummers, and common ſoldiers, the ſame with thoſe of the army. Their arms are the ſame with thoſe of the king's forces: but when called upon to quell mobs, they uſe Lochaber axes, a part of the ancient Scottiſh armour now in uſe only among themſelves.

32 Militia or trained bands.

The militia or trained band of the city conſiſt of 16 companies of 100 men each. They were in uſe to turn out every king's birth day; but only the officers now remain, who are choſen annually. They conſiſt of 16 captains and as many lieutenants and enſigns; the provoſt, as has already been mentioned, being the colonel.

The town guard are paid chiefly by a tax on the trading people; theſe being the only perſons formerly ſubject to watching and warding. This tax, however,

ever, amounts only to 1250l; and as the expence of the guard amounts to 1400l. the magiſtrates are obliged to defray the additional charge by other means.

But in the year 1805, in conſequence of a new ſyſtem of police being eſtabliſhed, the city guard was reduced to one lieutenant, two ſerjeants, two corporals, two drummers, and thirty men, the lord provoſt for the time being to be captain, without pay, and the company to be armed and clothed at the expence of the city, but their pay to be defrayed out of the general fund raiſed under the new police act; and the duty of this company is to attend upon his majeſty's commiſſioner to the general aſſembly of the church of Scotland, the magiſtrates and town council, the ſupreme courts of juſtice, and to act in general for the ſupport of the new ſyſtem of police.

33 Syſtem of police. The ſyſtem of police above alluded to, was eſtabliſhed in 1805 by act of parliament, under the authority of which the city and ſuburbs are divided into ſix diſtricts or wards for the more convenient execution of the purpoſes to which the act extends. The regulations included under this ſyſtem of police relate to cleanſing and lighting the ſtreets and paſſages in the city and ſuburbs, apprehending and puniſhing vagrants and diſorderly perſons, ſuppreſſing common begging, preventing nuiſances and obſtructions, and for other purpoſes connected with the preſervation of peace and good order. The management of the whole affairs under this ſyſtem of police is entruſted to the general and reſident commiſſioners. The general commiſſioners appointed by the act, are, the lord provoſt and magiſtrates of the city of Edinburgh, with the lord preſident of the court of ſeſſion, the lord juſtice clerk, the lord chief baron of the court of exchequer, the law officers of the crown, and ſeveral other public characters, in conjunction with the whole reſident commiſſioners in the different wards. There are to be ſeven reſident commiſſioners in each ward, the two higheſt in the liſt to go out, and two others to be elected in their ſtead annually; the commiſſioners to be occupiers of houſes valued at twenty pounds ſterling of free rent yearly, excepting in two wards, where occupying a houſe of twelve pounds rent is a ſufficient qualification. In each ward there are to be elected by the reſident commiſſioners, with the approbation of the general commiſſioners, an inſpector, and ſuch a number of officers of police and watchmen as may be neceſſary, the officers of police and watchmen upon duty having the authority and poſſeſſing the powers given by the law of Scotland to the office of conſtable.

The generalc ommiſſioners have the power of chooſing a ſuperintendant or maſter of police for the whole city and ſuburbs included in the act, and to appoint a clerk who ſhall do the duty of clerk to the general meetings, as well as to the court of police to be held by the ſuperintendant. The general commiſſioners alſo are authorized to fix the number of officers and watchmen to be employed in the different wards. The ſuperintendant of police having been appointed by the commiſſioners, is to receive from the ſheriff depute of the county of Edinburgh the authority of a ſheriff ſubſtitute, as well as a commiſſion of ſheriff depute within the city and liberties from the lord provoſt who is principal ſheriff within theſe bounds, that the ſuperintendant acting as maſter or judge of police may have the full powers of a magiſtrate in the execution of his duty. By the powers with which the ſuperintendant is inveſted, he may commit offenders to the tolbooth or to bridewell for a period not exceeding 60 days, and impoſe fines for offences not exceeding 40 ſhillings ſterling, and give judgment in damages for any ſum not exceeding three pounds ſterling with the expences in either caſe. From the ſentences of the ſuperintendant there is no appeal to the ſheriff depute of the county, or to the lord provoſt as ſheriff principal within the city. The ſuperintendant of police is alſo the billet-maſter within his bounds, and the inſpectors of wards are billet-maſters within their ſeveral wards. The inſpectors alſo have the powers of procurator fiſcals with reſpect to all proſecutions for offences committed within their bounds.

The expences neceſſary to carry the above act into execution, are to be defrayed from a fund raiſed by aſſeſſment on the inhabitants of three per cent. on the free rent of houſes, ſhops or warehouſes, and for the expences of clothing and alimenting the perſons committed to bridewell a farther aſſeſſment not exceeding $\frac{1}{4}$ per cent. of the free rent of ſuch houſes, &c. For the purpoſe of aſcertaining rents, ſurveyors are appointed; and if the rent fixed by them ſhould be over-rated, an appeal may be made to a committee of the general commiſſioners ſpecially appointed.

The office of the ſuperintendant of police is in the Lawnmarket. The operation of the act has only continued for a few months (September 1805) and although ſome complaints have been made of its rigorous execution, ariſing probably from ſuch unavoidable and unforeſeen circumſtances as frequently occur in the eſtabliſhment of a new ſyſtem, yet there is every reaſon to hope, that it will prove highly beneficial for the preſervation of peace and good order in the city and ſuburbs over which it extends.

34 Number of inhabitants. The number of inhabitants in the city of Edinburgh is ſomewhat uncertain, and has been very variouſly calculated. By a ſurvey made in the year 1775, it appears that the number of families in the city, Canongate, and other ſuburbs, and the town of Leith, amounted to 13,806. The difficulty therefore is to fix the number of perſons in a family. Dr Price fixes this number at $4\frac{1}{15}$; Mr Maitland, at $5\frac{1}{1}$; and Mr Arnot, at 6; ſo that, according to this laſt gentleman, the whole number of inhabitants is 82,836; to which he thinks 1400 more may be added for thoſe in the garriſon, hoſpitals, &c.

The following table exhibits a comparative view of the population of the city of Edinburgh and ſuburbs taken in different years. The laſt enumeration made in 1801 by act of parliament is ſuppoſed to be conſiderably defective in the real amount of the inhabitants, as an alarm was induſtriouſly ſpread that it was done with a view to the impoſition of new taxes. This, it appeared, induced many to conceal the names and number of the individuals in their families.

1678	35,500
1722	40,420
1755	57,195
1775	70,430
1791	84,886
1801	82,560

There

Edinburgh, Edinburgh-ſhire.

There are in Edinburgh 14 incorporations, capable of chooſing their own deacons, viz. The royal college of ſurgeons; the corporations of goldſmiths, ſkinners, furriers, hammermen, wrights and maſons, taylors, bakers, butchers, ſhoemakers, weavers, waukers, bonnet-makers, and merchant company.

35 Plenty of proviſions.

The markets of Edinburgh are plentifully ſupplied with all ſorts of proviſions. Freſh butcher meat, as well as fowl and fiſh, if the weather permit, may be had every day; and no city can be better ſupplied with garden ſtuffs. The Edinburgh ſtrawberries particularly are remarkably large and fine. A ſtriking inſtance of the plenty of proviſions with which Edinburgh is ſupplied was obſerved in the year 1779, when ſeveral large fleets, all of them in want of neceſſaries, arrived in the Forth, to the amount of about 500 ſail, and having on board at leaſt 20,000 men; yet the increaſed conſumption of proviſions, which certainly enſued upon the arrival of ſo many ſtrangers, made not the leaſt increaſe in the rate of the markets, inſomuch that ſeveral victualling ſhips ſent down by the navy board returned without opening their hatches. The city mills are let to the corporation of bakers in Edinburgh; and the bread made in the city is remarkable for its goodneſs.

Edinburgh is ſupplied with water brought for ſome miles in pipes, and lodged in two reſervoirs, from whence it is diſtributed through the city both to public wells and private families. A revenue accrues to the town from the latter, which muſt undoubtedly increaſe in proportion as the city extends in magnitude.

There are but few merchants in Edinburgh, moſt of them reſiding at the port of Leith; ſo that the ſupport of the city depends on the conſumption of the neceſſaries as well as the ſuperfluities of life. There are five different ſorts of people on whom the ſhopkeepers, publicans, and different trades depend: 1. The people of the law, who are a very reſpectable body in the city. 2. The number of young people of both ſexes who come to town for their education, many of the parents of whom come along with them. 3. The country gentlemen, gentlemen of the army and navy, and people who have made their fortunes abroad, &c. all of whom come to attend the public diverſions, or to ſpend their time in ſuch a manner as is moſt agreeable to them. 4. The vaſt concourſe of travellers from all parts. 5. Moſt of the money drawn for the rents of country gentlemen is circulated among the bankers or other agents.

At Edinburgh there are excellent manufactures of linen and cambrics; there are alſo manufactures of paper in the neighbourhood, and printing is carried on very extenſively. But for ſome time the capital branch about Edinburgh has been building: which has gone on, and ſtill continues to do ſo, with ſuch rapidity, that the city has been increaſed exceedingly in its extent; and it is not uncommon to ſee a houſe built in a few months, and even inhabited before the roof is quite finiſhed.

EDINBURGHSHIRE, or MIDLOTHIAN, is bounded on the north by the frith of Forth and the river Amond, which divides it from Weſtlothian or Linlithgow; on the eaſt by Haddingtonſhire; on the ſouth by the counties of Lanark, Peebles, and Berwick; and at the weſt corner by part of the county of Linlithgow. It extends about 30 miles in length, and its breadth varies from 16 to 20; containing in all about 360 ſquare miles, or 230,400 Engliſh acres. The ſurface of the country is pleaſant, having much level ground, interſperſed with ſome hills, watered with many agreeable ſtreams, and ſheltered and decorated with woods. The arable land, which may be calculated about one third of the whole, is in a ſtate of high cultivation, and affords excellent crops. The two great ridges of hills which paſs through the county, called the *Moorfoot* and the *Pentland* hills, afford paſture; the former is far ſuperior in quality to the latter: in theſe hills it is generally remarked that the north ſide of the hill is the fineſt and beſt paſture, contrary to what we ſhould be apt, *a priori*, to imagine. Like the other parts of the country, this diſtrict experiences the conſequences of an inſulated ſituation; being ſubject to that inſtability and uncertainty, that the climate in one day exhibits the weather of every ſeaſon of the year; the cold eaſt winds in the ſpring are exceedingly detrimental to fruit, and in autumn the *haars* or miſts from the ſea, are apt to whiten and wither the corns before they are ripe. The immediate vicinity of many of the farms to the metropolis affords the opportunity of procuring ſtreet dung eaſily, and has been of material advantage in improving the land; it has this diſadvantage, however, that by long continuance the fields become very full of weeds, particularly the *ſcaller* or wild muſtard; it is imagined that this would be obviated by throwing the field out in paſture for a few years, and afterwards liming it well before ploughing. The chief rivers of the county of Edinburgh, are the *North* and *South Eſks*, which, uniting, fall into the frith of Forth at the town of Muſſelburgh; the *Amond*, which falls into the ſame frith at the village of Cramond, and the water of *Leith*, which forms the harbour of that town: all of theſe abound with trout. The iſlands of Inchkeith and Cramond, and of Inchmickery, alſo belong to this county. Few diſtricts of Scotland afford more minerals than the county of Edinburgh; it abounds everywhere with coal, limeſtone, and freeſtone of ſuperior quality; and iron ore of different ſpecies is very abundant; compound ſtone, called *petuntſe*, is found in great quantity in the Pentland hills, and has been ſucceſsfully employed in the manufacture of Britiſh porcelain. In the pariſh of Ratho is found a fine ſpecies of whetſtone or hone; and in the pariſh of Duddingſtone, at Brickfield, is found clay, fit for making earthen ware. The hills are compoſed of *porphyry* and *baſaltic whinſtone*, which in many places, particularly Arthur's Seat and Craig-Lockhart, exhibit regular forms. Near Glencroſs, and in the Braid-hills, are found great veins of the heavy ſpar, or barytes, which is often an attendant on metallic veins, eſpecially of lead and copper. All the hills contain ſpecimens of zeolites, jaſpers, ſpars, &c. From the vicinity to the metropolis, numerous ſeats of nobility and gentry are everywhere to be ſeen. Beſides the city of Edinburgh and its ſuburbs, in which we may include the town of Leith, this county contains ſeveral large towns and villages, as Dalkeith, Muſſelburgh, Liberton, Laſſwade, and Gilmerton, and is divided into 31 pariſhes, of which the following is the population at two different periods.

Edinburgh-ſhire.

	Pariſhes.	Population in 1755.	Population in 1790—1798.
1	Borthwick	910	858
	Calder, Weſt	1294	1289
	Canongate	4500	6200
	Carrington	555	329
5	Cockpen	640	1123
	Colingtown	792	1395
	Corſtorphine	995	1037
	Cramond	1455	1485
	Cranſtoun	725	839
10	Crichton	611	900
	Currie	1227	1300
	Dalkeith	3110	4366
	Duddingſton	989	910
	Edinburgh	31,122	31,898
15	Fala	312	372
	Glencroſs	557	385
	Heriot	209	300
	Inveresk	4645	5392
	Kirknewton	1157	812
20	Laſſwade	2190	3000
	Leith, North	2205	2409
	Leith, South	7200	11,432
	Libbertoun	2793	3457
	Midcalder	1369	1251
25	Newbottle	1439	1295
	Newton	1199	1135
	Pennycuick	890	1721
	Ratho	930	825
	St Cuthberts	12,193	32,947
30	Stow	1294	1400
31	Temple	905	593
		90,412	122,655
			90,412
		Increaſe,	32,243

EDITOR, a perſon of learning, who has the care of an impreſſion of any work, particularly that of an ancient author: thus, Eraſmus was a great editor; the Louvain doctors, Scaliger, Petavius, F. Sirmond, Biſhop Walton, Mr Hearne, Mr Ruddiman, &c. are likewiſe famous editors.

EDOM, or ESAU, the ſon of Iſaac and brother of Jacob. The name of Edom, which ſignifies *red*, was given him, either becauſe he ſold his birthright to Jacob for a meſs of red pottage, or by reaſon of the colour of his hair and complexion. Idumæa derives its name from Edom, and is often called in Scripture the land of Edom. See the next article.

EDOM, or IDUMÆA, in *Ancient Geography*, a diſtrict of Arabia Petræa; a great part alſo of the ſouth of Judæa was called *Idumæa*, becauſe occupied by the Idumæans, upon the Jewiſh captivity, quite to Hebron. But the proper Edom or Idumæa appears not to have been very extenſive, from the march of the Iſraelites, in which they compaſſed it on the ſouth eaſtwards, till they came to the country of the Moabites. Within this compaſs lies Mount Hor, where Aaron died; marching from which the Iſraelites fought with King Arad the Canaanite, who came down the wilderneſs againſt them (Moſes). And this is the extent of the *Idumæa Propria* lying to the ſouth of the Dead ſea; but in Solomon's time extending to the Red ſea, (1 Kings ix. 26.)

EDMUND I. and II. See (*Hiſtory of*) ENGLAND.

1 Definition.

EDUCATION may be defined, that ſeries of means by which the human underſtanding is gradually enlightened, and the diſpoſitions of the human heart are formed and called forth between earlieſt infancy and the period when we conſider ourſelves as qualified to take a part in active life, and, ceaſing to direct our views ſolely to the acquiſition of new knowledge or the formation of new habits, are content to act upon the principles which we have already acquired.

2 Particulars comprehended under the definition.

This comprehends the circumſtances of the child in regard to local ſituation, and the manner in which the neceſſaries and conveniencies of life are ſupplied to him; the degree of care and tenderneſs with which he is nurſed in infancy; the examples ſet before him by parents, preceptors, and companions; the degree of reſtraint or licentiouſneſs to which he is accuſtomed; the various bodily exerciſes, languages, arts, and ſciences, which are taught him, and the method and order in which they are communicated; the moral and religious principles which are inſtilled into his mind; and even the ſtate of health which he enjoys during that period of life.

3 Various modes of education have prevailed.

In different periods of ſociety, in different climates, and under different forms of government, various inſtitutions have naturally prevailed in the education of youth; and even in every different family, the children are educated in a different manner, according to the differences in the ſituation, diſpoſitions, and abilities, of the parents. The education of youth being an object of the higheſt importance, has not only engaged the anxious care of parents, but has likewiſe often attracted the notice of the legiſlator and the philoſopher.

4 Plan.

What our readers have therefore a right to expect from us on this article is, 1ſt, That we give an account of ſome of the moſt remarkable inſtitutions for the education of youth which have been legally eſtabliſhed or have accidentally prevailed among various nations and in various periods of ſociety. 2dly, That we alſo give ſome account of the moſt judicious and the moſt fanciful plans which have been propoſed by thoſe authors who have written on the ſubject of education. And, laſtly, That we venture to preſent them with the reſult of our own obſervations and recollections on this important head.

5 Education in a ſavage ſtate.

In the infancy of ſociety, very little attention can be paid to the education of youth. Before men have riſen above a ſavage ſtate, they are almoſt entirely the creatures of appetite and inſtinct. The impulſe of appetite hurries them to propagate their ſpecies. The power of inſtinctive affection is often, though not always, ſo ſtrong as to compel them to preſerve and nurſe the fruit of their embraces. But even when their wants are not ſo urgent, nor their hearts ſo deſtitute of feeling as to prompt them to abandon their new-born infants to the ferocity of wild beaſts or the ſeverity of the elements, yet ſtill their uncomfortable and precarious ſituation, their ignorance of the laws of nature, their deficiency of moral and religious principles, and their want of dexterity or ſkill in any of the arts of life; all theſe together muſt render them unable to regulate the education of their children with much attention and ſagacity. They may relate to them the wild inconſiſtent tales, in which all their notions concerning ſuperior beings, and all their knowledge of the circumſtances and tranſactions of their anceſtors, are contained; they may teach them to bend the bow, to point their arrows, to hollow the trunk of a tree into a canoe, and to trace the almoſt imperceptible path of an enemy or a wild beaſt over dreary mountains or through intricate foreſts: but they cannot impreſs their minds with juſt ideas concerning their ſocial relations, or concerning their obligations to a Supreme Being, the framer and upholder of nature; they teach them not to repreſs their irregular appetites, not to reſtrain the ſallies of paſſion when they exceed juſt bounds or are improperly directed; nor can they inform their underſtandings with very accurate or extenſive views of the phenomena of nature. Beſides, they know not how far implicit obedience to his parents commands is to be required of the boy or youth, nor how far he ought to be left to the guidance of his own reaſon or humour. Among ſavages the influence of parental authority ſoon expires, nor is the parent ſolicitous to maintain it. As the eagle expels his young from his lofty neſt as ſoon as they become able to ſupport themſelves in the air; ſo the ſavage generally ceaſes to care for his child, or aſſume any power over him, as ſoon as he becomes capable of procuring the means neceſſary for his own ſubſiſtence. Savages being ſcarce connected by any ſocial ties, being unacquainted with the reſtraint of civil laws, and being unable to contribute in any great degree to the maintenance or protection of one another; each individual among them, as ſoon as he attains that degree of ſtrength and dexterity which may enable him to procure the neceſſaries of life, ſtands ſingle and alone, independent on others, and ſcorning to ſubmit to their commands. The parent, conſcious of his inability to confer any important benefits on his child, after he has advanced even a very ſhort way towards manhood, no longer endeavours to controul his actions; and the child proud of his independence, ſcarce ſubmits to aſk his parents advice. And even before his reaching this period of independence, ſo few are the benefits which parents can beſtow (being confined to ſupplying the neceſſaries of life, and communicating the knowledge of a very few of the rudeſt ſimpleſt arts), that children regard them with little deference, nor do *they* always inſiſt on implicit ſubmiſſion. Want of natural affection, and conſciouſneſs of ſuperior ſtrength, often prompt the parent to abuſe the weakneſs of his child. Yet though ſmall the ſkill with which the ſavage can cultivate the underſtanding or form the diſpoſitions of his child, though few the arts which he can teach him, and though not very reſpectful or ſubmiſſive the obedience or deferences which he requires: yet there is one quality of mind which the ſavage is more careful to inſpire than thoſe parents who are directed in educating their children by all the lights of civilized ſociety. That quality indeed is abſolutely neceſſary to fit the ſavage for his ſituation; without it, the day on which he ceaſed to enjoy the protection of his parents would moſt probably be the laſt day of his life: That quality is Fortitude. We may perhaps think, that the hardſhips to which the young ſavage is from the period of his birth unavoidably expoſed, might be enough to inſpire him with fortitude; but as if theſe were inſufficient, other means are applied to inſpire him with what the Stoics have regarded as the firſt of virtues. He is compelled to ſubmit to many hardſhips unneceſſary, but from a view to this. Children are there called to emulate each other in bearing the ſevereſt torments. Charlevoix relates, that he has ſeen a boy and girl bind their arms together, place a burning coal between them, and try who could longeſt endure without ſhrinking the pain to which they thus expoſed themſelves.

6
The ſavage indebted chiefly to nature and circumſtances for his education.

Still, however, the young ſavage owes his education rather to nature and to the circumſtances in which he is placed, and the accidents which befal him, than to the kindneſs or prudence of his parents. Nature has endowed him with certain powers of underſtanding, ſentiments, ſenſations, and bodily organs; he has been placed in certain circumſtances, and is expoſed to a certain train of events; and by theſe means chiefly, not by the watchful induſtry of inſtructors, does he become ſuch as he appears when he has reached the years of maturity.

7
Education in an improved ſtate of ſociety.

But man was not deſigned by his wiſe and beneficent Creator to remain long in a ſavage ſtate; the principles of his nature incline him to ſocial life. Reaſon, diſtinguiſhing the ſuperior advantages to be enjoyed in ſociety, concurs with the ſocial principle in his breaſt, in prompting him to ſeek the company and converſation of others of the human race. When men enter into ſociety, they always unite their powers and talents, in a certain degree, for the common advantage of the ſocial body. In conſequence of this, laws come in time to be inſtituted; new arts are invented; progreſs is made in the knowledge of nature; moral duties are better underſtood and defined; juſter ideas are gradually acquired of all our ſocial relations; friendſhip, love, filial, parental, and conjugal affection, all are heightened and refined. All theſe advantages do not inſtantly reſult from men's entering into a ſocial ſtate; the improvement of the human mind, and the civilization of ſociety, are gradual and progreſſive: But as it is natural for men to unite in a ſocial ſtate, ſo it is no leſs natural for ſociety to be gradually improved and civilized till it attain a high degree of perfection and refinement.

8
Attention to the education of youth a natural conſequence of civilization.

When men have attained to ſuch knowledge and improvement as to be entitled to a more honourable appellation than that of ſavages, one part of their improvements generally conſiſts in their becoming more judicious and attentive in directing the education of their youth. They have now acquired ideas of dependence and ſubordination; they have arts to teach and knowledge to communicate; they have moral principles to inſtil; and have formed notions of their relation and obligations to ſuperior powers, which they are deſirous that their children ſhould alſo entertain. Their affection to their offspring is now alſo more tender and conſtant. We obſerve at preſent in that ſtate of ſociety in which we live, that the poor who can ſcarce earn for themſelves and their children the neceſſaries of life, are generally leſs ſuſceptible of parental affection, in all its anxious tenderneſs, than the rich, or thoſe whom Providence hath placed in eaſy circumſtances; and we may make uſe of this fact in reaſoning concerning the different degrees of the ſame affection felt by the ſavage and the member of a civilized ſociety. The ſavage may be conſidered as the poor man, who with difficulty procures the neceſſaries of life even for himſelf; the other, as the man in affluent circumſtances, who is more at leiſure to liſten to the voice of tender and generous affection.

In this improved ſtate of ſociety, the education of youth is viewed as an object of higher importance. The child is dearer to his parent; and the parent is now more capable of cultivating the underſtanding and rectifying the diſpoſitions of his child. His knowledge of nature, and his dexterity in the arts of life, give him more authority over a child than what the ſavage can poſſeſs. Obedience is now enforced, and a ſyſtem of education is adopted; by means of which the parent attempts to form his child for acting a part in ſocial life. Perhaps the legiſlature interferes; the education of the youth is regarded as highly worthy of public concern: it is conſidered that the fooliſh fondneſs or the unnatural caprice of parents may, in the riſing generation, blaſt the hopes of the ſtate.

9
Public eſtabliſhments for education among the ancients.

In reviewing ancient hiſtory, we find that this actually took place in ſeveral of the moſt celebrated governments of antiquity. The Perſians, the Cretans, and the Lacedemonians, were all of them too anxious to form their youth for diſcharging the duties of citizens to intruſt the education of the children ſolely to the parents. Public eſtabliſhments were formed among thoſe nations, and a ſeries of inſtitutions enacted, for carrying on and regulating the education of their youths: Not ſuch as our European univerſities, in which literary knowledge being the ſole object of purſuit, the ſtudent is maintained ſolely at his parents expence, and attends only if his parents think proper to ſend him; but of a very different nature, and on a much more enlarged plan.

10
Among the ancient Perſians.

The Perſians, according to the elegant and accurate account delivered by Xenophon in the beginning of his Cyropædia, divided the whole body of their citizens into four orders; the boys, the youth, the full-grown men, and thoſe who were advanced beyond that period of life during which military ſervice was required. For each of theſe orders particular halls were appropriated. Each of them was ſubjected to the inſpection of twelve rulers. The adults and the ſuperannuated were required to employ themſelves in the performance of particular duties, ſuitable to their age, their abilities, and their experience; while the boys and the youth were engaged in ſuch a courſe of education as ſeemed likely to render them worthy and uſeful citizens.

The boys were not employed, in their places of inſtruction, in acquiring literary accompliſhments; for to ſuch the Perſians were ſtrangers. They went thither to learn juſtice, temperance, modeſty; to ſhoot the bow, and to launch the javelin. The virtues and the bodily exerciſes were what the Perſians laboured to teach their children. Theſe were the direct, and not ſubordinate, purpoſes of their ſyſtem of education. The maſters uſed to ſpend the greateſt part of the day in diſpenſing juſtice to their ſcholars; who carried before them actions for thefts, robberies, frauds, and other ſuch grounds of complaint againſt one another.—Such were the means by which the Perſians endeavoured to inſtil, even in early youth, a regard for the laws of natural equity, and for the inſtitutions of their country. Till the age of 16 or 17, the boys were buſied in acquiring thoſe parts of education. At that period they ceaſed to be conſidered as boys, and were raiſed to the order of the youths. After they entered this order, the ſame views were ſtill attended to in the carrying on of their education. They were ſtill inured to bodily labour. They were to attend the magiſtrates, and to be always ready to execute their commands. They were led out frequently to the chaſe; and on ſuch expeditions they were always headed by the king, as in time of war. Here they were taught to expoſe themſelves fearleſsly to danger; to ſuffer, without repining or complaint, hunger, thirſt, and fatigue; and to content themſelves with the coarſeſt, ſimpleſt fare, for relieving the neceſſities of nature. In ſhort, whether at home or out on ſome hunting expedition, they were conſtantly employed in acquiring new ſkill and dexterity in military exerciſes, new vigour of mind and body, and confirmed habits of temperance, fortitude, abſtinence, patience, patriotiſm, and noble integrity. After ſpending ten years in this manner, their courſe of education was completed; they were admitted into the claſs of the adults, and were eſteemed qualified for public offices. It muſt not eſcape our notice, that the citizens were not compelled to ſend their children to paſs through this courſe of education in the public halls; but none except ſuch as paſſed through this courſe of education were capable of civil power, or admitted to participate in public offices or public honours.

Such are the outlines of that ſyſtem of education which Xenophon repreſents as publicly eſtabliſhed among the Perſians. Were we able to preſerve in a tranſlation all the manly and graceful ſimplicity of that enchanting author, we would have offered to the peruſal of our readers the paſſage in which he has deſcribed it: but conſcious of being inadequate to that taſk, we have preſumed only to extract the information which it contains.

11
Remarks on Xenophon's account of Perſian education.

Perhaps, however, this ſyſtem of education did not ſubſiſt preciſely as the eloquent diſciple of Socrates deſcribes it among that rude and ſimple people. On other occaſions he has commemorated ſuch inſtances of their barbarity, as would tempt us to think them incapable of ſo much order and ſo much wiſdom. Perhaps, as the diſcoverers of the new would have ſometimes conferred on the inhabitants of that hemiſphere, in the accounts of them with which they entertained their friends in Europe, amazing degrees of moral and political wiſdom, of ſkill and dexterity in the arts, of induſtry and valour, which thoſe uncivilized children of nature were afterwards found not to poſſeſs; ſo the Athenian philoſopher has alſo aſcribed to the Perſians prudence and attention in regulating the education of their youth beyond what people in ſo rude a ſtate can poſſibly exert.

But if we examine into the principles on which this ſyſtem of education proceeds, without concerning ourſelves whether it once actually prevailed among the Perſians, or is the production of the fine imagination of Xenophon, we will find it peculiarly ſuitable for a nation juſt emerging from the rudeneſs and ignorance of barbarity to a knowledge of ſocial and civil relations, and of the duties connected with ſuch relations. They have ſacrificed their independence to obtain the comfort

comfort and ſecurity of a ſocial ſtate. They now glory in the appellation of citizens, and are deſirous to diſcharge the duties incumbent on a citizen. They muſt inform their children in the nature of their ſocial relations, and impreſs them with habits of diſcharging their ſocial duties; otherwiſe the ſociety will ſoon be diſſolved, and their poſterity will fall back into the ſame wild miſerable ſtate from which they have emerged. But perhaps the circumſtances, or abilities, or diſpoſitions of individuals, render them unequal to this weighty taſk. It becomes therefore naturally an object of public care. The whole ſocial body find it neceſſary to deliberate on the moſt proper means for diſcharging it aright. A plan of education is then formed; the great object of which is, to fit the youth for diſcharging the duties of citizens. Arts and ſciences are hitherto almoſt wholly unknown: and all that can be communicated to the youth is only a ſkill in ſuch exerciſes as are neceſſary for their procuring ſubſiſtence, or defending themſelves againſt human enemies or beaſts of prey; and habits of performing thoſe duties, the neglect of which muſt be fatal to the ſociety or the individual.

Such is the ſyſtem of education which we have ſurveyed as eſtabliſhed among the Perſians; and perhaps we may now be leſs ſuſpicious than before of Xenophon's veracity. It appears natural for a people who have reached that degree of civilization in which they are deſcribed, and have not yet advanced farther, to inſtitute ſuch an eſtabliſhment. Some ſuch eſtabliſhment alſo appears neceſſary to prevent the ſociety from falling back into their former barbarity. It will prevent their virtue and valour from decaying, though it may perhaps at the ſame time prevent them from making any very rapid progreſs in civilization and refinement. Yet the induſtry, the valour, the integrity, and the patriotiſm which it inſpires, muſt neceſſarily produce ſome favourable change in their circumſtances; and that change in their circumſtances will be followed by a change in their ſyſtem of education.

12 Among the Cretans.

The Cretans, too, the wiſdom of whoſe laws is ſo much celebrated in the records of antiquity, had a public eſtabliſhment for the education of their youth. Minos, whom they revered as their great legiſlator, was alſo the founder of that eſtabliſhment. Its tendency was ſimilar to that of the courſe of education purſued among the Perſians,—to form the ſoldier and the citizen. We cannot preſent our readers with a very particular or accurate account of it; but ſuch as we have been able to procure from the beſt authorities we think it our duty to lay before them.

The Cretans were divided into three claſſes; the boys, the youth, and the adults. Between ſeven and ſeventeen years of age, the boy was employed in learning to ſhoot the bow, and in acquiring the knowledge of his duties as a man and a citizen, by liſtening to the converſation of the old men in the public halls, and obſerving their conduct. At the age of ſeven, he was conducted to the public halls to enter on this courſe of education. He was taught to expoſe himſelf boldly to danger and fatigue; to aſpire after ſkill and dexterity in the uſe of arms and in the gymnaſtic exerciſes; to repeat the laws and hymns in honour of the gods. At the age of ſeventeen he was enrolled among the youth. Here his education was ſtill continued on the ſame plan. He was to exerciſe himſelf among his equals in hunting, wreſtling, and the military exerciſes; and while thus engaged, his ſpirits were rouſed and animated by ſtrains of martial muſic played on ſuch inſtruments as were then in uſe among the inhabitants of Crete. One part of the education of the Cretan youth, in which they were particularly deſirous to excel, was the Pyrrhic dance; which was the invention of a Cretan, and conſiſted of various military evolutions performed to the ſound of inſtruments.

Such were the principles and arts in which the Cretan legiſlature directed the youth to be inſtructed. This courſe of education could not be directed or ſuperintended by the parent. It was public, and carried on with a view to fit the boy for diſcharging the duties of a citizen when he ſhould attain to manhood.

13 Remarks on the Cretan education.

It is eaſy to ſee, that ſuch a ſyſtem of education muſt have been inſtituted in the infancy of ſociety, before many arts had been invented, or the diſtinctions of rank had ariſen; at a time when men ſubſiſted in a conſiderable degree by hunting, and when the intercourſe of nations was on ſuch a footing, that war, inſtead of being occaſional, was the great buſineſs of life. Such a ſyſtem of life would then naturally take place, even through no ſage legiſlator had ariſen to regulate and enforce it.

14 Among the Lacedemonians.

Lycurgus, the celebrated lawgiver of Lacedemon, thought it neceſſary to direct the education of youth in a particular manner, in order to prepare them for paying a ſtrict obedience to his laws. He regarded children as belonging more properly to the ſtate than to their parents, and wiſhed that patriotiſm ſhould be ſtill more carefully cheriſhed in their breaſts than filial affection. The ſpirit of his ſyſtem of education was pretty ſimilar to that of thoſe which we have juſt viewed as ſubſiſting among the Perſians and the Cretans.

As ſoon as a boy was born, he was ſubmitted to the inſpection of the elders of that tribe to which his parents belonged. If he was well ſhaped, ſtrong, and vigorous, they directed him to be brought up, and aſſigned a certain portion of land for his maintenance. If he was deformed, weak, and ſickly, they condemned him to be expoſed, as not being likely ever to become an uſeful citizen. If the boy appeared worthy of being brought up, he was intruſted to the care of his parents till he attained the age of ſeven years; but his parents were ſtrictly charged not to ſpoil either his mind or his bodily conſtitution by fooliſh tenderneſs. Probably, too, the ſtate of their manners was at that time ſuch as not to render the injunction peculiarly neceſſary.

At the age of ſeven, however, he was introduced to a public claſs, conſiſting of all the boys of the ſame age. Their education was committed to maſters appointed by the ſtate; and what was chiefly inculcated on them in the courſe of it, was ſubmiſſive obedience and reſpect to their ſuperiors; quickneſs and brevity in their converſation, and replies to ſuch queſtions as were put to them; dexterity and addreſs in performing what was commanded them, and firmneſs and patience in bearing every pain or hardſhip to which they might be expoſed. One of the means uſed to form them to habits of activity and addreſs, was to permit, nay,

nay, to direct them to commit little acts of theft; which, if they performed them ſo dexterouſly as to avoid detection, they might afterwards boaſt of as noble exploits: but if detected in ſuch enterpriſes, the awkward artleſs boy was expoſed both to puniſhment and diſgrace. To avoid the puniſhment and diſgrace incurred by being detected in an act of theft, the Spartan boy would often ſuffer with unſhrinking fortitude the ſevereſt torments. It is related of one of them, that rather than be diſcovered with a young fox under his cloak, which he had ſtolen, he ſuffered the little animal to tear open his bowels. Not content with beholding the children ſuffer by ſubmitting voluntarily to ſuch hardſhips, the Spartans alſo endeavoured to form them to fortitude, by whipping them on their religious feſtivals, ſometimes with ſuch ſeverity that they expired under the laſh. The Lacedemonian youth were alſo taught ſuch bodily exerciſes, and the uſe of ſuch warlike weapons, as were neceſſary to render them expert and ſkilful ſoldiers.

15
Remarks.

They too, as well as the Cretans and Perſians, among whom we have ſeen ſimilar modes of education adopted, were to be citizens and ſoldiers; not huſbandmen, mechanics, artiſts, merchants, &c. Their mode of education, therefore, was ſimple and uniform. Its aim was, to make them acquainted with the nature of their ſocial duties, and to form them to ſuch vigour of body and ſuch firmneſs of mind as might render them fit for the ſtation in which they were to be placed, and adequate to the part which they were to act. This eſtabliſhment for education was perfectly conſiſtent with the other parts of that legiſlature which was inſtituted by Lycurgus. Youth educated among the Lacedemonians could hardly fail to become worthy members of that ſingular republic. Let us not however regard the Spartans as ſingularly inhumane in their treatment of youth. Let us reaſcend, in imagination, to that period in the progreſs of ſociety from rudeneſs to refinement, which they had reached when Lycurgus aroſe among them. What were then their circumſtances, their arts and manners, their moral principles, and military diſcipline? Not very different from thoſe which the laws of Lycurgus rendered ſo long ſtationary among them. He, no doubt, rectified ſome abuſes, and introduced greater order and equality. But man is not to be ſo eaſily metamorphoſed into a new form. As you cannot, at once, raiſe an acorn to a venerable oak; ſo neither will you be able to change the ſavage, at once, into the citizen. All the art or wiſdom of Lycurgus, even though aſſiſted by all the influence of the prophetic Apollo, could never have eſtabliſhed his laws among his countrymen, had not their character and circumſtances previouſly diſpoſed them to receive them. But, grant this, and you muſt, of conſequence, allow, that, what to us may appear cruel and inhumane, muſt have affected their feelings in a different manner. The change introduced in the treatment of youth by the eſtabliſhment of this ſyſtem of education was probably recommended by its being more humane than what before prevailed. Corrupted as are our manners, and effeminate our modes of education; yet we would not perhaps act wiſely in laying them aſide, to adopt in their ſtead thoſe of ancient Sparta. But the Spartan education was peculiarly well fitted to form citizens for the republic of Lycurgus; it was happily adapted to the ſtate of ſociety in which it was introduced. And, if we ſhould inquire by what means Lycurgus was enabled to fix the arts, the manners, and in ſhort the civilization of his country, for ſo long a period, in a ſtationary ſtate; we would perhaps find reaſon to aſcribe that effect to the public eſtabliſhment which he inſtituted for the education of youth; to his confining the Spartan citizens to the profeſſion of arms, and aſſigning all ſervile offices to the Helots; and to his prohibiting the uſe of gold and ſilver. Among theſe however his eſtabliſhment for education occupies the chief place. Never was any ſtate adorned with more patriotic citizens than thoſe of Sparta. With them every private affection ſeemed to be ſwallowed up by the *amor patriæ*: the love of their country was at leaſt their ruling paſſion. Pœdaretes being rejected when he offered himſelf a candidate for a ſeat among the council of three hundred, returned home, rejoicing that there were in Sparta no fewer than three hundred whom his countrymen found reaſon to regard as better citizens than himſelf. This was not a ſeeming joy, aſſumed to conceal the pain which he ſuffered from the diſappointment; it was heartfelt and ſincere. Such were the effects of their ſyſtem of education.

16
Education among the other nations of antiquity.

When we turn our eyes from the Perſians, the Cretans, and the Spartans, to the other nations of antiquity; we nowhere behold ſo regular a ſyſtem of public education. Among the Athenians and the Romans, the laws did not deſcend to regulate in ſo particular a manner the management of the youth. Theſe nations gradually emerged from a ſtate of the rudeſt barbarity, to that poliſhed, enlightened, and civilized ſtate which rendered them the glory and the wonder of the heathen world: but in no part of their progreſs from the one ſtate to the other do we find any ſuch eſtabliſhment ſubſiſting among them. So various, however, are the circumſtances which form and diverſify the character of nations, that we cannot reaſonably conclude, becauſe no ſuch eſtabliſhments exiſted among the Athenians and Romans, that therefore their exiſtence was unnatural among thoſe nations who poſſeſſed them. But though the education of youth was managed in a different manner among theſe and moſt other nations in the ancient world, than by public eſtabliſhments, which detached children from the care of their parents; yet ſtill it was everywhere regarded as an object of the higheſt importance. As the manners of mankind gradually improved to a ſtate of refinement; as the invention of arts, and the diſcovery of ſcience, gradually introduced opulence and luxury; connubial, parental, and filial affection gradually acquired greater ſtrength and tenderneſs. Of conſequence, children experienced more of their parents care; and that care was directed to form them for acting a becoming part in life. According to the circumſtances of each nation, the arts which they cultivated, and the form of government under which they lived; the knowledge which they ſought to communicate to their children, and the habits which they endeavoured to impreſs upon them, were different from thoſe of other nations: And again, according to the different circumſtances, tempers, abilities, and diſpoſitions of parents, even the children of each family were brought up in a manner different from that in which thoſe of other families were managed. The Athenians, the Romans, the Carthaginians, conducted each of them the education of their youth in a different manner, becauſe they had each different objects in view. But having conſidered the moſt ſingular eſtabliſhments for education which prevailed in the ancient world, it ſeems unneceſſary for us to deſcend to a particular account of the manner which every nation, or fantaſtic individual, thought proper to purſue in bringing up their youth. It will probably be more uſeful and entertaining to our readers, if we next preſent them with a view of ſome of the moſt judicious or fanciful plans of education which have been propoſed by the writers on that ſubject.

17 Quinctilian.

One of the moſt reſpectable writers on education among the ancients is the celebrated Quinctilian. He taught rhetoric in Rome during the reign of Domitian, and under ſeveral of the other emperors. When he retired from the exerciſe of his employment as a teacher of rhetoric, he ſpent his leiſure in the compoſition of a treatiſe, not merely on rhetoric, but on the moſt proper means for educating a boy ſo as to render him both an eloquent orator and a good man.

In that valuable treatiſe, he enters into a minute detail of all that appears to him moſt likely to conduce to thoſe important ends.

As ſoon as the boy enters the world, he would have the greateſt care to be uſed in ſelecting thoſe who are to be placed about him. Let his nurſe have no impediment of ſpeech. It will be happy for him, if his parents be perſons of ſenſe and learning. Let his tutor, at leaſt, poſſeſs theſe qualifications. As ſoon as he attains the diſtinct uſe of his organs of ſpeech, let him be initiated in the firſt elements of literature. For as he is capable of diſtinguiſhing and remembering at a very early age; ſo his faculties cannot poſſibly be employed in a more advantageous manner. And even at this early period of life, let maxims of prudence and the firſt principles of morals be inculcated upon his mind by the books which are put into his hands, and even by the lines which he copies in learning the art of writing. The Greek language was to the Romans in the days of Quinctilian, what the Latin and Greek and French are to us at preſent, an acquiſition held indiſpenſably neceſſary to thoſe who aſpired to a liberal education; and Quinctilian judges it proper that the boy ſhould begin his application to letters with the Greek language in preference to his mother tongue.

This judicious writer next examines a queſtion which has been often agitated, Whether a domeſtic or a public education is liable to the feweſt inconveniences, and likely to be attended with the greateſt advantages? And he is of opinion, that in a domeſtic education the boy is in danger of being corrupted by injudicious fondneſs and evil example; is not rouſed by the ſpur of emulation; and is deprived of proper opportunities for acquiring a juſt idea of his own power, or that activity and dexterity which he will afterwards find ſo neceſſary when he comes to act a part in life: While in a public education, which was preferred by ſome of the moſt renowned nations of antiquity, the morals are not greatly expoſed to corruption, emulation is rouſed, friendſhips are formed, all the powers of the mind are called forth to act with new vigour, and the youth is prepared for performing his part on the great theatre of the world. Quinctilian, therefore, wiſhes that parents would place their children in public ſeminaries of education.

When a boy is committed to a maſter's care, the maſter's attention muſt be firſt directed to diſcover his diſpoſitions and the extent of his capacity. Of his capacity he will form a favourable judgment, not from his ſprightlineſs, nor even from his quickneſs of apprehenſion, but from his modeſty, docility, and virtuous diſpoſitions. If the boy poſſeſs theſe laſt qualifications, the maſter will rejoice in him, as likely to give him ſatisfaction and do him honour. According to his temper and diſpoſitions, let the boy be treated with mildneſs or ſeverity; but never let ſeverity extend to blows. Let the boy be allured and led, by the moſt artful and inſinuating treatment, to do his duty; there will then be no occaſion to puniſh him for neglecting it.

As Quinctilian's profeſſed object was, not merely to give general directions for forming the heart and cultivating the underſtanding, but to form a particular character in life, the ſcholar and the orator; he finds it neceſſary to enter into minute details concerning the manner in which the boy is to be inſtructed in ſpeaking, writing, grammar, and compoſition; of which it does not appear neceſſary for us to take particular notice in this place. Muſic and geometry, he thinks, ought to make a part of the young orator's ſtudies; as being uſeful to render him accurate in reaſoning, and capable of reliſhing the beauties of the poets. He is alſo of opinion, that the boy ſhould not be confined to one branch of ſtudy, without being allowed to attempt others till he have made himſelf maſter of that. Let ſeveral parts of literature engage his attention by turns: let him dedicate a conſiderable portion of his time to them. He may thus acquire habits of induſtrious application which will remain with him through life.

With the tender attention of a good man, this ſenſible and elegant writer ſtill accompanies his pupil through the courſe of his ſtudies; anxiouſly inſiſts that he be placed under a maſter diſtinguiſhed for purity of morals, and for no mean abilities in his profeſſion; directs his memory to be ſtored with the nobleſt paſſages of the poets, orators, and hiſtorians; and carefully diſcuſſes and refutes thoſe opinions which repreſent genius as above induſtry. The remaining part of his work being employed on the principles of rhetoric, without containing any thing on the ſubject of education in general, it is not neceſſary that we ſhould here preſent an analyſis of it to our readers. But ſince Quinctilian was ſo diſtinguiſhed, not only as a rhetorician, but as an inſtructor of youth, and diſplays ſo much good ſenſe and ſo ſolid a judgment, formed on long experience, in whatever he advances on the ſubject of education; we could not, without extreme negligence, omit taking notice of him under this article, and affording our readers an opportunity of being inſtructed by liſtening to his ſentiments on this head.

18 Milton's Treatiſe on Education.

The name of John Milton is ſo much revered in Britain, that his ſentiments on any ſubject are intereſting to Britons. His life was dedicated to ſtudy: During a part of it, he was employed in the taſk of inſtructing youth;

youth; and among his other works we find a treatiſe on education. He had himſelf been educated according to that plan which has long been eſtabliſhed in the Engliſh univerſities; but with that mode of education he was not ſatisfied. The object of his directions is chiefly to form a ſcholar. He conſidered himſelf as qualified to exhibit a model of "a better education, in extent and comprehenſion far more large, and yet of time far ſhorter, and of attainment far more certain, than any that had yet been in practice." The following is the ſubſtance of his treatiſe.

As the end of learning is to cultivate our underſtandings, and to rectify our diſpoſitions; therefore the deſign of our applying to the ſtudy of languages cannot be merely that we may commit to memory the words of which they conſiſt, or that we may acquire a knowledge of their analogy and ſtructure; but that we may enrich our minds with the treaſures of wiſdom which they contain. But in the preſent modes of education this deſign does not appear to be kept in view. The learner of Latin is burdened with rules, and themes, and verſes, and orations; but no care is taken to make him maſter of the valuable knowledge which the claſſics contain. And when he advances a little farther, he is driven into the thorny paths of logic and metaphyſics. So, when his ſtudies are completed, and he is conſidered as having received a liberal education, he is almoſt as deſtitute of real knowledge as when he firſt entered a ſchool.

But to render learning truly beneficial, inſtead of the ſchool and univerſity education which youth at preſent receive, let the place of both ſchool and univerſity be ſupplied by an academy, in which they may acquire all that is taught at either, except law and phyſic. Let the academy afford accommodation for 150 perſons; 20 of whom may be ſervants and attendants. As many academies as are neceſſary may be afterwards erected on the model of this one. Let the youth who are introduced into this academy begin their ſtudies with learning the principal rules of grammar from ſome good elementary book. In their pronunciation of Latin, let them be taught to follow the pronunciation of the Italians; as that of the Engliſh is indiſtinct, and unſuitable to the genius of the language. Next, read to them ſome entertaining book on education; ſuch as, the three firſt books of Quinctilian in Latin, and Cebes, Plutarch, or ſome other of the Socratic diſcourſes, in Greek; and be careful to ſeize every opportunity of inſpiring them, by ſeaſonable lectures and explanations, with love for learning, admiration of great and virtuous characters, and a diſpoſition to cheerful obedience. At the ſame time, but at a different hour of the day, let them be inſtructed in the rules of arithmetic and the elements of geometry. Between ſupper and bedtime, inſtruct them in the principles of religion and the ſacred hiſtory. From the writers on education let your pupils paſs to the authors on agriculture, to Cato, Varro, and Columella. Before half theſe authors be read, they cannot but be pretty well qualified to read moſt of the proſe authors in the Latin language; and they may now, with great propriety, learn the uſe of the globes, and make themſelves acquainted with the ancient and modern maps. Let them, about the ſame time, begin the ſtudy of the Greek tongue, and proceed in it as in the Latin: they will not fail to overcome, in a ſhort time, all the difficulties of grammar; after which they will have acceſs to all the treaſures of natural knowledge to be found in Ariſtotle and Theophraſtus. In the ſame manner they may make themſelves acquainted with Vitruvius, Seneca, Mela, Celſus, Pliny, and Solinus. And having thus paſſed through the principles of arithmetic, geometry, aſtronomy, and geography, with a general compact of phyſics; let them next turn their attention to mathematics, in which they may begin with the practical branch of trigonometry, which will ſerve as an introduction to fortification, architecture, and navigation. To teach them the knowledge of nature, and inſtruct them in the arts of life, let them have the aſſiſtance and inſtructions, not merely of maſters who are acquainted only with books, but of men whoſe ſkill has been obtained by actual practice, even of artiſts and mechanics. Next, let the poets obtain their attention; and they will now read them with eaſe and pleaſure. From the poets let your pupils proceed to the moraliſts; and, after acquainting themſelves with them, they may be allowed the entertainment of ſome of the beſt Greek, Latin, and Italian dramatic compoſitions. From theſe let them proceed to politics; let them here ſtudy the law of Moſes, the admirable remains of the ancient lawgivers of Greece, the Roman tables, edicts, and pandects, concluding with the inſtitutions of their mother-country. Now let them be more particularly inſtructed in the principles of theology; for by this time they may have acquired the Hebrew language, together with the Chaldee and the Syriac dialect, and may therefore read the Scriptures in their original language. When their minds are thus furniſhed, they will be able to enter into the ſpirit of the nobleſt hiſtorians and poets. To get by heart, and repeat in a proper manner, paſſages from the writings of ſome of theſe, will have the happieſt effects in elevating their genius. Let this ſtately edifice be crowned with logic and rhetoric. Far different would be the effects of ſuch a courſe of education, from thoſe produced by any which is at preſent purſued. We ſhould then ſee abler writers, more eloquent ſpeakers, and wiſer ſtateſmen. Similar to this, probably, was the courſe taught in the famous ſchools of Pythagoras, Plato, Iſocrates, and Ariſtotle. This would unite the advantages of an Athenian and a Spartan education: for our pupils ſhould be taught the exerciſes of wreſtling and fencing, and the whole military diſcipline.

19 Remarks.

Such are the ideas of our admired Milton on the ſubject of education. An enthuſiaſtic admirer of the ſciences, arts, and inſtitutions of Greece and Rome; from his religious and political principles, no friend to the univerſities; it was natural for a man of his learning and ingenuity, in an age of innovation, and influenced by ſuch prejudices, to form ſuch a project as that which we have ſurveyed. He ſeems not to have reflected, that it is neceſſary for children to be long occupied in obtaining a familiar acquaintance with words, before they can gain from books any knowledge of things; overlooking this circumſtance, and perceiving plainly that the mode of education which then prevailed confined the attention of youth almoſt wholly to words, he could not but regard the ſcheme which he propoſed as likely to produce very happy effects. His obſervation, that the appearances of external nature are among the firſt objects which attract the attention of youth, which he communicates by directing his pupils to peruſe the writers on agriculture and natural hiſtory as near the beginning of their ſtudies as poſſible; if not altogether juſt, yet muſt be allowed to be nearly ſo. Perhaps human actions and paſſions, and the ſeries of events which happen around us, are, by the time at which we begin our application to learning, the objects which moſt frequently and ſtrongly engage our attention: But the appearances of external nature are at leaſt the next object of our regard.

20
Locke's Treatiſe on Education.

Mr Locke, to whoſe abilities and noble deſire to be uſeful to the world his country is ſo much indebted, has written, among other things, on the education of youth. He was capable of thinking for himſelf; but more deſirous of rendering himſelf uſeful, than of being admired for ſingularity. He is therefore an author to whom we ought to liſten, at leaſt, with reſpectful attention. If Quinctilian and Milton had been employed as teachers of youth, Mr Locke had been converſant with the world, had inquired into the principles of human nature, and had no doubt endeavoured to examine without prejudice the effects of thoſe modes of education of which he diſapproves. When we conſider, that, to render himſelf uſeful to the riſing generation, he could deſcend from the heights of ſcience to tranſlate the fables of Æſop, and to perform other humble taſks in literature, which a philoſopher of leſs benevolence and virtue would have diſdained; we cannot but look with veneration and gratitude on ſo exalted a character. In his Treatiſe on Education, the two great objects which Mr Locke keeps in view are, 1ſt, To preſerve and ſtrengthen the bodily conſtitution; 2dly, To inform the underſtanding with uſeful knowledge, and to cheriſh good diſpoſitions in the heart.

21
Bodily conſtitution.

In his directions on the firſt of theſe heads, he ſeems extremely anxious to prevent parents and others in whoſe hands children are placed, from injuring them by ill-directed tenderneſs. Plain fare, ſimple and light clothing, abſtinence from phyſic and from ſtrong liquors, he earneſtly recommends as the moſt judicious means for preſerving and confirming the health of the child. In all his gratifications let the ſtricteſt moderation be obſerved. If you permit him to indulge pretty freely in ſleep, at leaſt cauſe him to get up at an early hour in the morning. In one thing, however, few parents will be willing to comply with Mr Locke's advice. He not only directs that the child's feet be frequently bathed in cold water, but even expreſſes a wiſh, that his ſhoes were always kept in ſuch a condition as to admit water freely. This he thinks likely to fortify the conſtitution of the body in ſuch a manner, as to render him leſs liable, in the courſe of life, to ſuch diſeaſes as ariſe from any unuſual expoſure to wetneſs or cold, than others whoſe feet have been more carefully kept dry. Though he had proſecuted his ſtudies with a deſign to enter into the profeſſion of phyſic, yet ſo unfavourable an opinion did he entertain of the effects produced by medical preparations on the human conſtitution, that he earneſtly inſiſts on the parent to beware of adminiſtering any of them to his child. From the deſire which Mr Locke diſcovers to have children expoſed to hardſhips, and reſtrained from indulgence, in order to confirm the health and invigorate the conſtitution, we may conjecture him to have been an admirer of that ſevere mode of education which uſually prevails in the earlier periods of the exiſtence of ſociety. He ſeems to have thought, that if a boy be brought up like a Huron or a Spartan, he muſt neceſſarily become robuſt and healthy; without reflecting, that of thoſe children who are ſubjected to ſuch a courſe of education, too great a proportion are unable to ſurvive it: ſuch is the natural delicacy of the human frame.

22
Cultivation of the powers of the mind.

When he turns his attention to the cultivating of the underſtanding, and the forming of the diſpoſitions, Mr Locke ſtill deſervedly claims the regard of the parent and the preceptor. With a virtuous indignation he reprobates that negligence and folly by which we generally corrupt the heart and ſpoil the temper of children, even in that period of infancy; ſo as to render them incorrigible when they advance farther in life. Their appetites are pampered, all their deſires are gratified: and if we are at any time diſpoſed to refuſe what they aſk, they have an all-powerful engine to compel our compliance with their wiſhes. They aſſail us with tears; and we then yield to their requeſts, however hurtful to themſelves or inconvenient to us. We often ſtudiouſly inſtruct them in vicious tricks, and call forth their evil paſſions. At ſo early an age, their rage or cunning can ſcarcely injure us; and we reflect not that habits of peeviſhneſs and deceit muſt be peculiarly hurtful to themſelves.

But though all the fooliſh deſires of children ought not to be gratified, and though we ſhould carefully avoid leading them into any bad habit; yet it is not neceſſary nor prudent to treat them with harſhneſs or ſeverity. Let them be formed to obedience from their earlieſt years: let them be accuſtomed to ſubmit implicitly to the direction of thoſe on whom they depend. But beware of ſouring their temper and depreſſing their ſpirits by harſhneſs: and, on the other hand, remember that it is no leſs improper to give the boy a habit of neglecting his duty, except when he is allured to it by the hopes of reward. As he advances towards manhood, and attains the uſe of reaſon, you may admit him to greater familiarity, and allow him to follow his own inclinations more than at an earlier period: and if, inſtead of indulging all his freaks in childhood, you have carefully accuſtomed him to obedience and ſubmiſſion, without enforcing theſe by improper means, he will now be able to regulate his conduct with ſome degree of prudence.

But while caution is to be uſed in beſtowing rewards and inflicting puniſhments, ſtill rewards and puniſhments are indiſpenſably neceſſary in the management of the child. Inſpire your boy with a ſenſe of ſhame, and with a generous thirſt for praiſe. Careſs and honour him when he does well: treat him with neglect when he acts amiſs. This conduct will produce much better effects than if you were at one time to chide and beat him; at another, to reward him with a profuſion of ſweetmeats and playthings.

Think not that children are to be taught propriety of conduct by loading their memory with rules, directing them how to act on every particular occaſion. Burden them not with rules, but impreſs them with habits.

Be not deſirous of forming them at too early an age, to all that politeneſs and propriety of manners which you wiſh to diſtinguiſh them when they become men. Let them be taught an eaſy, graceful carriage of body: but give yourſelf no concern, though they now and then blunder againſt the punctilios of good breeding; time will correct their awkwardneſs.

With regard to that important queſtion, whether children ought to be ſent to a public ſchool, or are likely to be better trained up in a domeſtic education? ſo impoſſible is it for one maſter to extend his attention to a number of boys, and ſo likely is the contagion of vice to be caught among the crowd of a public ſchool, that a private ſeems more favourable than a public education to virtue, and ſcarce leſs favourable to learning.

When you reſolve to give your ſon a domeſtic education, be careful to regulate that domeſtic education in a judicious manner. Keep him at a diſtance from evil example: chooſe the moſt favourable ſeaſons for communicating inſtruction: ſtrictly enforce obedience; but never by blows, except in caſe of obſtinacy which you find otherwiſe incurable. If his engagements in life prevent the parent from ſuperintending and directing his ſon's education perſonally, let him commit him to the care of a virtuous and judicious tutor. Let the tutor be rather a man of experience in the world than of profound learning; for it is more neceſſary that the pupil be formed for conducting himſelf with prudence in the world, and be fortified againſt thoſe temptations to which he will be expoſed when he enters upon active life, than that his head be ſtuffed with Latin and logic.

Here Mr Locke, notwithſtanding that his own mind was ſtored with the treaſures of Grecian and Roman literature, takes occaſion to declare himſelf pretty freely againſt that application to ancient learning, which was then indiſpenſably required in the education of youth. He conſiders languages and philoſophy as rather having a tendency to render the youth unfit for acting a prudent and becoming part in life than forming for it: and he therefore inſiſts that theſe ſhould be but in a ſubordinate degree the objects of his attention.

Let the tutor encourage the child under his care to a certain degree of familiarity; let the pupil be accuſtomed to give his opinion on matters relative to himſelf: let him be taught juſtice, by finding injuſtice to others prejudicial to himſelf; let him be taught liberality, by finding it advantageous; let him be rendered ſuperior to teaſing his parents or tutor with complaints, by finding his complaints unfavourably received. That you may teach him to reſtrain every fooliſh or irregular deſire, be ſure never to indulge his wiſhes, ſave when you find the indulgence proper for him, and convenient for yourſelf. Curioſity, however, is a principle which ought to be induſtriouſly rouſed in the breaſt of the child, and cheriſhed there by meeting always the readieſt gratification. However you may oppoſe the boy's inclinations in other things, yet refuſe him not a proper portion of recreation: let him indulge in play, while he continues to play with keenneſs and activity; but ſuffer him not to loiter about in liſtleſs indolence. To reſtrain your child from foolhardy courage, point out to him the dangers to which it expoſes him: to raiſe him above timorous cowardice, and inſpire him with manly fortitude, accuſtom him from the earlieſt period of life to an acquaintance with ſuch things as he is moſt likely to be afraid of: ſubject him now and then to pain, and expoſe him to danger; but let ſuch trials be judiciouſly conducted.

Idleneſs or curioſity ſometimes leads children to cruelty in their treatment of ſuch animals as are placed within their power. Dogs, cats, birds, and butterflies, often ſuffer from their inhumanity. But when they ſeem inclined to ſuch cruelty, let them be carefully watched, and let every means be uſed to awake their hearts to generous ſenſibility. Allow them to keep tame birds, dogs, &c. only on condition of their uſing them with tenderneſs. Perhaps this unhappy diſpoſition to cruelty is occaſioned, or at leaſt foſtered, by people's laughing when they behold the impotent efforts of children to do miſchief; and often going ſo far as even to encourage them in maltreating thoſe creatures which are within their reach. We entertain them, too, with ſtories of fighting and battles; and repreſent characters diſtinguiſhed for atrocious acts of inhumanity as great and illuſtrious. But let ſuch practice be carefully refrained from, if you wiſh to inſpire your child with generous and humane ſentiments. Teach him gentleneſs and tenderneſs, not only to brute animals, but alſo to ſervants and companions.

Curioſity is to be rouſed and cheriſhed in the breaſt of the child: but by what means? Anſwer his inquiries readily: though his queſtions be put in awkward language, let not that hinder you from attending to the objects of them. Curioſity is natural to the human mind; and if you repreſs not the curioſity of the child, he will often be moved by its impulſe to the purſuit of knowledge. Let him find his eagerneſs in the purſuit of knowledge a ſource of applauſe and eſteem. Avoid the folly of thoſe who ſport with the credulity of children, by anſwering their queſtions in a ludicrous or deceitful manner.

You muſt, however, not only liſten with obliging attention to his queſtions, and ſtrive to gratify his curioſity; but even whenever he attempts to reaſon on ſuch ſubjects as are offered to his obſervation, be careful to encourage him: praiſe him if he reaſons with any degree of plauſibility; even if he blunders, beware of ridiculing or laughing at him. With regard to the boy's playthings: while you indulge him freely in innocent diverſions, give him ſuch playthings as may be neceſſary in the amuſements in which he engages, provided they be ſuch as he cannot make himſelf; but it will be ſtill better for him to exerciſe his dexterity and ingenuity in making them himſelf.

After throwing out theſe things concerning the general principles on which education ſhould be carried on, Mr Locke next proceeds to thoſe particular parts of knowledge in which he thinks every young gentleman ought to be inſtructed. In virtue, wiſdom, breeding, and learning, he comprehends all that is neceſſary to enable his pupil to act a reſpectable part in life.

In forming the boy to virtue, the firſt thing to be done is to inform him of the relation ſubſiſting between human creatures and a ſupreme independent Being, their creator, preſerver, and governor; and to teach him, that obedience and worſhip are due to that Being. But when you inform the child of the exiſtence of an inviſible Being, beware of impreſſing his mind with any notions concerning ſpirits or goblins, which may render him incapable of bearing darkneſs or ſolitude. In infancy our minds are, by the indiſcretion of thoſe about us, generally impreſſed with ſuch prejudices concerning a thouſand frightful forms, ever ready to aſſail or haunt us under the ſhade of night, that we become incapable of manly fortitude during the courſe of life: the ſoldier who will boldly face death in the field of battle, ſhall perhaps tremble and take to flight at the ruſtling of a few leaves, or the grunting of a hog in the dark. But were the imaginations of children not crazed with wild ſtories concerning ſpirits and hobgoblins, darkneſs would be no more alarming to them than light. After informing the child of the exiſtence of a Deity, and teaching him to pray to him; next labour to impreſs his mind with a veneration for truth, and habituate him to a ſtrict adherence to it on every occaſion. Endeavour alſo to render him gentle and good-natured.

The beſt means you can uſe to teach him wiſdom or prudence in conducting himſelf in the ordinary buſineſs and intercourſe of life, is to teach him to deſpiſe the mean ſhifts of cunning. The reſt muſt be learned by actual experience in life.

The decencies of life, comprehended under the word Good Breeding, form no inconſiderable part of a good education. In teaching theſe, two things are to be attended to: Inſpire the youth with a diſpoſition to pleaſe and oblige all with whom he is converſant; next, teach him how to expreſs that diſpoſition in a becoming manner. Let boiſterous roughneſs, haughty contempt of others, cenſoriouſneſs, impertinent raillery, and a ſpirit of contradiction, be baniſhed from his temper and behaviour. At the ſame time, beware of leading him to regard the mere forms of intercourſe as a matter of the higheſt importance. Remember that genuine good breeding is only an eaſy and graceful way of expreſſing good ſenſe and benevolence in his converſation and deportment.

Mr Locke, when he comes to give his opinion concerning thoſe parts of learning which are proper to be taught a young gentleman, and the manner in which they ought to be communicated, adviſes to initiate the child in the art of reading, without letting him know that he is engaged about a matter of any importance, or learning an accompliſhment which you are ſolicitous that he ſhould acquire. Preſent it to him in the form of an amuſement, or teach him to conſider it as an high honour to be permitted to learn his alphabet; otherwiſe he will turn from it with diſguſt. When by inſinuating arts you have allured him to apply to reading, put into his hands ſuch books as are plain, entertaining, and inſtructive. Inſiſt not on his reading over the Bible: inſtead of gaining any advantage from an indiſcriminate peruſal of it at this period of life, he is likely to acquire the moſt confuſed notions of religion, and an indifference for the ſacred volume during the reſt of life: yet it may be highly proper to cauſe him to peruſe ſome of its beautiful hiſtorical paſſages, and to familiarize him with its elegant and ſimple moral precepts. After learning to read his mother tongue, the boy's attention ought to be next directed to the art of writing. The eaſieſt way to teach him that art, is to get a plate engraved, after the model of any hand which you think moſt proper for his imitation. With this plate get a number of copies caſt with red ink; the letters of theſe the learner may trace with his pen filled with black ink: and he will thus in a ſhort time, and without much trouble to you or himſelf acquire a decent hand. As drawing is uſeful on many occaſions in life, if the boy be not naturally incapable of acquiring it, he may with great propriety dedicate ſome part of his time and attention to that art.

When the ſcholar has attained a tolerable degree of ſkill in writing, and in reading and ſpeaking his native language, he muſt next begin an acquaintance with other languages. Among theſe, the firſt object of his ſtudy will naturally be the Latin. Yet let none waſte their time in attempting to acquire a knowledge of Latin, but ſuch as are deſigned for ſome of the learned profeſſions, or for the life of a gentleman without a profeſſion. To theſe laſt it may be uſeful; to others it is wholly unſerviceable. But in learning the Latin tongue, a much happier method than burdening and perplexing him with rules of grammar, would be to make him ſpeak it with a tutor who was ſufficiently maſter of it for that purpoſe. Thus might he ſpend that time which is uſually occupied in acquiring this language, in learning ſome other neceſſary branches of education. But if you cannot conveniently have the boy taught the language by the way of converſation, let the introductory books be accompanied with an Engliſh verſion, which he may have eaſy recourſe to for the explanation of the Latin. Never perplex him with grammatical difficulties. Reflect that, at his age, it is impoſſible to enter into the ſpirit of thoſe things. Render every thing as eaſy and pleaſing as poſſible: for the attention will not fail to wander, even though you labour not to render the taſk diſagreeable. Skill in grammar may be uſeful; but it is to thoſe whoſe lives are to be dedicated to the ſtudy of the dead languages: that knowledge which the gentleman and the man of the world may have occaſion to derive from the treaſures contained in the ancient languages, may be acquired, without a painful ſtudy of proſody or ſyntax. As the learning of any language is merely learning words; if poſſible, let it be accompanied with the acquiſition of ſome real knowledge of things; ſuch as the nature of plants, animals, &c. their growth and propagation. But if you cannot or will not give your boy a private education, and are ſtill reſolved to ſend him to ſchool, to be whipped through the uſual courſe of Greek and Latin; at leaſt act with ſo much good ſenſe and humanity, as to inſiſt that he be not burdened and tormented with the compoſition of Latin themes and verſes. Neither let his memory be oppreſſed with whole pages and chapters from the claſſics. Such ridiculous exerciſes have no tendency, whatever prejudice may urge to the contrary, to improve him either in the knowledge of languages or of nature.

Mr Locke ſeems to wiſh that the French language, which in his days had attained to higher refinement and a more regular analogy than any of the other modern languages of Europe;—he ſeems to wiſh that the French were learned along with the Latin: and he wiſhes the ſtudy of theſe languages to be accompanied with the ſtudy of arithmetic, geography, hiſtory, and chronology. Let theſe branches of knowledge be communicated

communicated to the learner in one of the two languages; and he will thus acquire the language with greater facility. He next points out the advantages of the branches of knowledge which he recommends as proper to be learned together with the languages; but on that head he ſays nothing ſingular. One method which he recommends for facilitating the ſtudy of language is, to put into the youth's hands, as ſoon as he has acquired a tolerable knowledge of chronology, ſome of the moſt entertaining Latin hiſtorians; the intereſting nature of the events which they relate will not fail to command his attention, in ſpite of the difficulty which he muſt find in making out their meaning. The Bible and Tully's Offices will be his beſt guides in the ſtudy of ethics. The law of nature and nations, as well as the civil and political inſtitutions of his country, will form to him an important object, which he ought to ſtudy with the moſt careful attention. Rhetoric and logic, though generally regarded as objects of great importance in a liberal education, can neither of them contribute much with all their rules and terms, to render him an acute reaſoner or an eloquent ſpeaker; and it is therefore unneceſſary for him to honour them with very particular attention. Tully and Chillingworth will be more beneficial in teaching him to reaſon and to perſuade, than all the treatiſes on rhetoric and logic which he can poſſibly peruſe, or all the lectures on thoſe arts which he can gain opportunities to hear. In every art and every ſcience practice and experience are infinitely better than rules. Natural philoſophy, as contributing to inſpire the breaſt with warmer ſentiments of devotion, and ſerving alſo to many uſeful purpoſes in life, ought to make a part in the young gentleman's ſtudies. But the humble experimental writers on that ſubject are to be put into his hands in preference to the lofty builders of ſyſtems. As for Greek, our pupil is not to be a profeſſed ſcholar, but a gentleman and a man of the world: and therefore it does not appear neceſſary that Greek ſhould make a part in the ſyſtem of his education. But in none of theſe ſtudies will the pupil ever attain any proficiency, unleſs he be accuſtomed to method and regularity in the proſecution of them. In languages, let him gradually aſcend from what is ſimpleſt to what is moſt difficult: in hiſtory, let him follow the order of time; in philoſophy, that of nature.

Dancing, as contributing to eaſe and gracefulneſs of carriage, ought to make part in our young gentleman's education. Fencing and riding being faſhionable, cannot well be denied him. As he is likely, in the courſe of life, to have ſome leiſure hours on his hands, and to be ſometimes diſpoſed to active recreation, let him learn ſome mechanical trade, with the exerciſe of which he may agreeably fill up ſome of thoſe hours. If he is to poſſeſs any property, let him not be unſkilled in the management of accounts. Travel, inſtead of being uſeful, appears more likely to be hurtful to the underſtanding and morals of the traveller, unleſs deferred to a later period than that at which young men are uſually ſent out to complete their education by traverſing through foreign countries.

Here Mr Locke concludes his work with obſerving, that he does not offer it to the world as a full or comprehenſive treatiſe on the ſubject of education, but merely as the outlines of what occurred to him as moſt proper to be obſerved in breeding up a young gentleman not intended for any learned profeſſion or mechanical employment, but for acting a reſpectable part in life at the head of a competent hereditary fortune.

23 Remarks.

In conſidering the ſentiments of this reſpectable philoſopher on the ſubject of education, we perceive, that as he was, on the one hand, ſuperior to thoſe prejudices which render us incapable of diſtinguiſhing the defects or abſurdities of any cuſtom or inſtitution which has long prevailed; ſo, on the other hand, he was free from that ſilly vanity which diſpoſes thoſe who are ſubject to its influence to affect novelty and ſingularity of ſentiment on every ſubject which they conſider. Though a member of one of the univerſities, he heſitates not to declare himſelf againſt a very laborious attention to claſſical learning; and his reaſoning is, through the whole of his treatiſe, rather plain and ſolid than ſubtle or refined.

Yet, however we reſpect the ſoundneſs of his underſtanding or the benevolence of his intentions, we cannot avoid obſerving, that his opinions are not always ſuch as experience juſtifies. He had no doubt taken notice of ſome inſtances in which the too great anxiety of parents about the preſervation of their children's health was the very means of rendering their conſtitution feeble and tender through the courſe of life; and from that circumſtance might be led to propoſe thoſe expedients which he mentions for preſerving the health and ſtrengthening the conſtitution of children. But a little more obſervation or inquiry would have eaſily convinced him, that ſome of his expedients, inſtead of ſtrengthening the child's conſtitution, would in all probability ſhorten his days.

He had perhaps ſeen ſome of the heroes of claſſical literature, who were familiar with Demoſthenes and Cicero, and had Homer and Virgil at their finger ends, —he had ſeen ſome of thoſe gentlemen ſo overloaded with their cargo of Greek and Latin as to be unfit for the ordinary buſineſs and intercourſe of life; and ſuch inſtances might tempt him to forget the advantages which he himſelf, and a long ſeries of philoſophers, patriots, and ſtateſmen, with whoſe names the annals of our country are adorned, had derived from a regular claſſical education. But as we are afterwards to deliver our own ſentiments on the ſubject, we will not here extend our obſervations on Mr Locke to a greater length.

24 Rouſſeau.

An author more diſtinguiſhed than Mr Locke for tenderneſs of ſentiment, ſingularity, eloquence, and whim, has preſented the public with a work on the ſubject of education, in which, with unexampled boldneſs, he inveighs againſt all the eſtabliſhed modes, as well as reprobates whatever had been advanced by former writers on the ſubject; and at the ſame time, delineates a plan of education which he would perſuade us is infinitely ſuperior to thoſe which he explodes. This writer is the amiable and pathetic Rouſſeau: And though he be often vain, paradoxical, and whimſical; yet the charm of genius and ſentiment which adorns his writings will at leaſt engage our attention while he unfolds his opinions.

25 Imprudent management of children in infancy.

He ſets out with obſerving, that our buſineſs in the bringing up of children ſhould be, to ſecond and to call forth nature; and that, inſtead of this, we almoſt always oppoſe

oppoſe her intentions and operations. As ſoon as the child ſees the light, he is wrapped in ſwathing bands. His limbs are thus reſtrained from that free motion which is neceſſary to their growth and vigour; and even the internal parts of his frame are rendered incapable of their proper functions. Mothers are too proud or indolent, or too fond of gaiety and diſſipation, to ſubmit to the taſk of nurſing their own children. The poor infants are committed to ſome hireling nurſe, who not being attached to them by natural affection, treats them with negligence or inhumanity. But is that mother capable of any delicacy of ſentiment, who can permit another to ſuckle her child, and to ſhare with her, or perhaps wholly ſupplant her, in the filial affection of that child?

Again, When parents undertake the care of their infant children, they often injure them by miſtaken tenderneſs. They pamper them with delicate meats, cover them with warm clothes, and anxiouſly keep them at a diſtance from all that has the appearance of danger: not attending to the economy of nature, who ſubjects us in infancy to a long train of epidemical diſtempers, and expoſes us during the ſame period to innumerable dangers; the deſign of which doubtleſs is, to teach us a prudent concern for our own ſafety, and to ſtrengthen and confirm our conſtitutions.

A child no ſooner enters into life, than it begins to cry; and during a great part of infancy continues frequently to ſhed tears. We either attempt to ſoothe it into good nature, or ſeek to ſilence it by harſher means; and it is thus we infuſe into its infant mind thoſe evil paſſions which we afterwards preſume to impute to nature.

As the mother generally diſdains to nurſe her own child, ſo the father is ſeldom at leiſure to take any ſhare in the management of his education: he is put into the hands of a tutor. But that tutor whoſe time and attention can be purchaſed for money is unworthy of the charge. Either be yourſelf your ſon's preceptor, or gain a friend whoſe friendſhip to you ſhall be his ſole motive to undertake the taſk.

26
Management of Emilius during infancy.

After a few preliminary obſervations to the above purport, our author introduces his Emilius; in whoſe education he delineates that plan which he prefers. The preceptor whom he would aſſign Emilius muſt be young; and muſt dedicate his attention to Emilius alone, from the time when his pupil enters the world till he attain the full age of manhood. Emilius, to receive the full benefit of his preceptor's ſyſtem of education, and to afford full ſcope to it, muſt poſſeſs a genius of the middle claſs; no prodigy of parts, nor ſingularly dull; he muſt have been born to affluent circumſtances and an elevated rank in life. His preceptor is inveſted with the rights, and takes upon him the obligations, of both father and mother. Emilius is, when put into the hands of his preceptor, a well-ſhaped, vigorous, and healthy child. The firſt care of the preceptor is to provide him with a nurſe, who, as he is new born, muſt be newly delivered? it is of ſtill higher importance that ſhe be clean, healthy, virtuous, and of mild diſpoſitions. While ſuckling her charge, ſhe ſhall feed plentifully, chiefly on a vegetable diet. The child muſt be frequently bathed, in cold water if poſſible; if you begin with warm, however, uſe it by degrees colder and colder, till at length he is able to bear it entirely cold. He is not to be wrapped in ſwaddling clothes or rollers, or bound with ſtaybands; but put in good warm blankets, and in a roomy cradle: Let him ſtretch and move his limbs at freedom, and crawl about on hands and knees at his pleaſure. The greateſt care muſt now be taken to prevent the child from contracting any habits whatever: Suffer him not to uſe one arm more than another, or to eat or ſleep at ſtated hours. Prepare him for the enjoyment of liberty, by preſerving to him the exerciſe of his natural abilities, unfettered by any artificial habits.

As ſoon as the child begins to diſtinguiſh objects, let his education begin. Some objects are naturally agreeable, others frightful. Accuſtom him to look upon any object that may come in his way without being affrighted. Children are at firſt ignorant of local relations, and learn to diſtinguiſh them only by experience; and while Emilius is yet an infant, incapable of ſpeaking or walking, he may be aſſiſted in acquiring the knowledge of theſe.

In his feeble helpleſs condition, the child muſt feel many wants and much uneaſineſs; tears are the language which nature has given him to make known his diſtreſſes and wants. When the child cries, it would be much more prudent and humane to examine what he ſuffers or ſtands in need of, than, as is uſually done, to rock or ſing him aſleep; or, when theſe means ſucceed not, to threaten or uſe him brutally.

In managing children, as nature has endowed them with no ſuperfluous powers, we ought not to confine them from the free uſe of thoſe which they are able to exert. It is our duty to ſupply their deficiency both of mental and bodily powers; but while we are ready to adminiſter on every occaſion to their real wants, we muſt beware of gratifying their caprice or unreaſonable humours. In order to diſtinguiſh between their natural and fantaſtic wants, we muſt ſtudy the language and ſigns by which they expreſs their wiſhes and emotions. Though crying be the means which nature has given infants to enable them to procure relief or aſſiſtance, yet when they cry they are not always in need of either. They often cry from obſtinacy or habits of peeviſhneſs. But if, inſtead of attempting to ſoothe them by diverting their attention to other objects, we would on ſuch occaſions entirely neglect them, they would ſoon ceaſe to indulge in ſuch fits of crying.

When children begin to ſpeak, we are uſually anxious about their language and articulation, and are every moment correcting their blunders. But inſtead of hoping to teach them purity or correctneſs of ſpeech by ſuch means as theſe, let us be careful to ſpeak eaſily and correctly before them, and allow them to expreſs themſelves in the beſt manner they can. By ſuch means we will be much more likely to obtain our wiſhes in this matter. When they ſpeak, let us not liſten with ſuch ſolicitude as to relieve them from the neceſſity of uſing an open diſtinct articulation.

When the child attains the power of expreſſing himſelf in artificial language, he may then be conſidered as having reached the ſecond period of infancy. He needs not now to make known his wants by tears, and ſhould therefore be diſcouraged from the uſe of them. Let his tears be entirely neglected. He now begins to run about, and you are anxious to prevent him from hurting himſelf; but your anxiety can only render him peeviſh

peeviſh or timid. Remove him from any very alarming danger, and then ſuffer him to run about at his pleaſure. He will now and then bleed, and hurt himſelf; but he will become bold, lively, aud cheerful.

27
Subjection to authority.

In regulating the conduct of your child, let him know that he is dependant; but require not of him an implicit ſubmiſſion to your will. Let his unreaſonable deſires be oppoſed only by his natural inability to gratify them, or by the inconveniences attending the gratification. When he aſks what is neceſſary or reaſonable, let him inſtantly obtain it; when he aſks what is unreaſonable or improper, lend a deaf ear to all his entreaties and demands. Beware of teaching him to eſtabliſh his authority over you by means of the forms of politeneſs. A child will ſcarce take the trouble to addreſs you with *If you pleaſe*, unleſs he has been made to regard theſe as a ſet of magic ſyllables, by the uſe of which he may ſubject every perſon to his will. His *If you pleaſe* then means *I pleaſe*; *pray*, with him, ſtands for *do*. Though you put in his mouth the words of humility, his tone and air are thoſe of authority that *will* be obeyed.

Sacrifice not the preſent happineſs of your child for the ſake of any diſtant advantage.

Be not too anxious to guard him againſt natural evil. The liberty which he enjoys while he is now and then permitted to expoſe himſelf to blows, or cold, or wetneſs, is more than a ſufficient compenſation for all that he thus ſuffers.

28
Ideas of moral obligation.

Seek not to impreſs him with ideas of *duty* or *obligation*. Till children reach the years of diſcretion, they are incapable of any notions of the diſtinctions of morality. Avoid therefore even the uſe of the terms by which they are expreſſed in their hearing. While they continue to be affected only by ſenſible objects, ſeek not to extend their ideas beyond the ſphere of ſenſation. Try all the powers of language, uſe the plaineſt and moſt familiar methods you can contrive; you ſhall ſtill be unable to give the boy at this age any juſt ideas of the diſtinction between right and wrong. He may readily conceive, that for one ſet of actions you will puniſh him, and that by another he will obtain your approbation; but farther than this his ideas of *right* and *wrong*, of *virtue* and *vice*, cannot yet be carried.

The powers of the human mind are gradually unfolded. At firſt, the infant is capable only of perception; by and by, his inſtincts and paſſions begin to exert their force; at length, as he advances towards manhood, reaſon begins to act, and he becomes able to feel the beauty of virtue and the deformity of vice.

But though you ſeek not to regulate his conduct by notions of *duty*, yet let him feel the yoke of neceſſity. Let him know, that as he is weaker than you, he muſt not, therefore, expect that you ſhould be ſubject to his will; and that, as he has neither ſkill nor ſtrength to control the laws of nature, and make every object around him bend to his pleaſure, he cannot hope to obtain the gratification of all his wiſhes. Thus you teach him virtue before he knows what virtue is; and call forth his reaſon without miſleading or perverting it. Let him feel his impotence; but forbid him not to think, that if he had power there would be no reaſon why he might not at pleaſure even turn the world upſide down.

Hitherto you have given your pupil no verbal inſtructions, nor muſt you yet attempt to inſtruct him by any other means than experience; let all his knowledge be literally of his own acquiſition.

Let not the parent who has obſerved the conduct of children brought up in the uſual way be afraid that, if his child ſhould be treated like our pupil, he would become ſtupid and vicious. Nature ſends not human beings into the world with a prediſpoſition to vice: we ſow the ſeeds of it in the infant heart; and by our abſurd modes of treatment, we alſo enfeeble and pervert the powers of the underſtanding.

But from the hour of his birth till he attain the age of twelve, the education of Emilius ſhall be purely negative. Could we but bring him up healthy and robuſt, and entirely ignorant, till that period, the eyes of his underſtanding would then be open to every leſſon: free from the influence of habit and prejudice, his paſſions would not then oppoſe us; and we might render him the wiſeſt and moſt virtuous of men. If we can but loſe time, if we can but advance without receiving any impreſſions whatever, our gains are unſpeakable. Nature gives the powers of every mind ſome particular direction: but that particular bias, impreſſed by the hand of nature, cannot be diſtinguiſhed before the period we have mentioned; and if you counteract nature, inſtead of ſeconding her views, the conſequences cannot but be highly unfavourable both to the heart and the underſtanding of your pupil.

Perhaps, in the midſt of ſociety, it may be difficult to bring up our pupil without giving him ſome idea of the relations between man and man, and of the morality of human actions. Let that, however, be deferred as long as poſſible.

Were Emilius to witneſs a ſcene of anger, and to aſk the cauſe of the appearances which he beheld, he ſhould be told that the perſons were affected with a fit of ſudden illneſs. We might thus perhaps prevent the unhappy effects of ſuch an example.

The firſt moral notions which ſhould be communicated to the child are thoſe of property. To communicate the ideas of property to our pupil, we will direct him to take poſſeſſion of ſomething; for inſtance, of a piece of ground belonging to ſome other perſon, and in a ſtate of cultivation. Let him cultivate this ſpot of ground anew, ſow it with ſeeds, and look eagerly forward to the time of harveſt in the hopes of reaping the fruit of his labours. In the mean time, let the proprietor of the ground take notice of what is done, deſtroy your pupil's riſing crop, and complain of the injuſtice done him. While the boy laments his loſs and the diſappointment of his hopes, in all the bitterneſs of grief, let the proprietor of the ground ſtill inſiſt on the injury done him, and complain of what he ſuffers by the purpoſe for which he himſelf had cultivated and ſown the ground being fruſtrated. Our pupil, now ſenſible of the reaſonableneſs of the other's claims, will deſiſt from his lamentations, and only beg to have ſome other ſpot aſſigned him which he may cultivate at his pleaſure without offending any perſon. This he will juſtly conſider as his own property, to the productions of which raiſed by his own labour he has an excluſive right, and in the occupying of which none ought to moleſt him. In ſome ſuch manner as this may the nature of property, the idea of which eaſily refers in the inſtance to the firſt occupier, and afterwards the exchange of property, be explained to him.

Another inſtance of the manner in which the pupil is now to be managed may not be improper in this place. He is poſſibly ſo rude and boiſterous as to ſpoil or break whatever is within his reach. Be not angry with him, however: if he break the utenſils which he has conſtant need of, be in no haſte to ſupply him with others in their room; let other things be removed out of his way: if he break the windows of his apartment, let him be expoſed night and day to the cold; complain not of the inconvenience yourſelf, but order matters ſo that he may feel it. After ſome time, let them be mended up; and if he break them again, change your method. Tell him calmly, “ Theſe windows are mine; I took care to have them put there; and I will prevent their being again broken, by confining you in a dark room.” Let all his endeavours to avoid this prove ineffectual. Let him be actually confined, and be liberated only on propoſing and agreeing to the condition of breaking no more windows. When he propoſes this condition, be ready to liſten to him; obſerve that it is well thought on, and that it is a pity he did not think of it ſooner. Conſider this engagement between you as ſacred; treat him as before, and you cannot fail to attain the end in view.

The moral world now opens to us: But no ſooner are we able to diſtinguiſh between right and wrong, than we become deſirous to conceal thoſe inſtances in which we act wrong. Lying is therefore a vice of which your pupil is now apt to be guilty: you cannot always prevent, but you can puniſh; but let the puniſhments which you inflict appear to the child only the natural conſequences of his conduct. If he is in any inſtance convicted of a lie, let his aſſertions no longer gain credit. By this means, ſooner than by precepts, or any other ſpecies of puniſhment, will you be able to reclaim him from the habit of lying.

The methods generally taken to render children virtuous are prepoſterous and fooliſh. To render them generous and charitable, we give them money, and bid them beſtow it in alms, while we ourſelves give nothing; but the parent or maſter, and not the child, ſhould beſtow the alms. Example might produce the wiſhed-for effect. Beſides, children are ſtrangers to the value of money. A gingerbread cake is more to them than a hundred guineas. Though you teach them to give away money, till you perſuade them to part readily with thoſe things which they value moſt, you do not inſpire them with generoſity. Would you make them liberal by ſhowing them that the moſt liberal is always beſt provided for? this is to teach covetouſneſs, not liberality. Example is the only means by which you can, at this period, hope to teach your pupil any of the virtues.

The only leſſon of morality that can with any propriety be inculcated on children, is to injure no perſon. Even the poſitive precept of doing good, muſt be conſidered as ſubordinate to this negative one of doing no harm. The moſt virtuous and the moſt exalted of characters, is the man who does the leaſt harm to his fellow creatures.

In a public education, it will be neceſſary to attempt the communication of moral inſtruction at an earlier period than in a private one. In a private education, it will always be beſt to allow the moral powers of children to ripen as much as poſſible before you endeavour to inform and direct them by precepts.

There is an inequality among geniuſes; and fond mothers and fathers may be diſpoſed to plead for exceptions in favour of ſuch of their children as they view with a partial eye. “ This boy's mind is more capacious, his powers are riper, than thoſe of others.” But however great the ſeeming diſparity of geniuſes may be, it is at bottom but inconſiderable. Let the age of children be therefore regarded as a common meaſure by which their treatment is to be regulated.

However quick and tenacious the memories of children may ſeem, they can derive little advantage from the exertions of memory till ſuch time as judgment begins to act. All the knowledge that they acquire in the courſe of the uſual ſyſtem of education, is merely the knowledge of words. The languages, geography, chronology, in ſhort all that they are taught, and called to diſplay ſo oſtentatiouſly at this period of life, ſerve no other purpoſe than to fill their minds with words.

29
Hiſtory, how far proper to be put into the hands of boys.

Hiſtory is eſteemed a proper thing to be put into the hands of children. But except you wiſh to confine their attention to the external and phyſical actions, it is almoſt nothing they can acquire by the peruſal of it. And if diveſted of the moral diſtinctions of actions, of the workings of the paſſions, and the complication of intereſts, what is there to render hiſtory entertaining? We may indeed eaſily teach them to repeat the words *kings*, *emperors*, *wars*, *conqueſts*, *revolutions*, *laws*: but of the things which you uſe theſe words to denote, you will find they are hitherto incapable of forming any clear ideas.

But the mere knowledge of words is not ſcience; make your pupil acquainted with things, and he will not fail to acquire their names. Emilius muſt never be ſet to get any compoſition by heart, not even fables: be careful to place before him thoſe ſcenes and objects, the images of which it may be uſeful for him to have impreſſed on his memory; but by no other means ſeek to aſſiſt him to improve that faculty.

Emilius ſhall not even learn to read till he attain the age of twelve: for, before that period, it can be of no benefit to him; and the labour would only make him unhappy during that period of life which is naturally the golden part of our days. But when he has attained the proper age, matters ſhall be ſo ordered, that he ſhall find his ignorance of letters an inconvenience. A card ſhall be ſent him, which being unable to read, he will apply to ſome of thoſe about him. They may be unwilling to oblige him, or otherwiſe engaged. If, at length, it is read to him, that may be when it is now too late to take advantage of ſome agreeable invitation which it contained. This may be two or three times repeated. At length he becomes eager to learn to read; and accompliſhes that almoſt without aſſiſtance.

The principle on which we proceed, is to leave the pupil almoſt wholly under his own direction, ſeemingly

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at leaſt; to lead him to acquire new accompliſhments, ſolely from the deſire of increaſing his powers, and extending his influence; and humbly to follow nature, not to force her.

As we are deſirous of cultivating his underſtanding, the means which we employ for that purpoſe is, to cultivate thoſe abilities on which it depends; he is always active and in motion. Let us firſt make him a man in point of health and vigour, and he will ſoon become a man in underſtanding.

By our conſtant attention to the welfare of children, we render it unneceſſary for them to attend to it themſelves. What occaſion has your ſon or pupil to obſerve whether the aſpect of the ſky threaten rain, when he knows that you will take care to have him ſheltered from a ſhower? or to regulate the length of his excurſions, when he is ſure that you will not ſuffer him to loſe his dinner?

While matters are ſo ordered that Emilius thinks himſelf ſubject only to his own will, though all his motions are regulated according to your pleaſure; inſtead of becoming fantaſtic and capricious, he inſenſibly acquires the habit of keeping utility in view in all his actions.

The firſt objects which engage the attention of children are the appearances of the material world around them: our firſt ſtudy is a kind of experimental philoſophy; our inſtruments and inſtructors are our hands, our feet, and our eyes. By exerciſing theſe bodily organs, the boy will acquire more real knowledge even in the period of childhood, than if he ſhould dedicate nine-tenths of his time to books, from the age of ſix to ſixty. All who have examined, with any ſagacity, the characters, circumſtances, and manners of the ancients, have agreed in attributing to their gymnaſtic exerciſes that ſuperior ſtrength of body and mind which renders them objects of admiration to the moderns.

Our pupil's clothes cannot be too light and eaſy. If tight and cloſe, they fetter and confine his joints and limbs, and likewiſe obſtruct the circulation of the blood; if accuſtomed to warm clothing, he will ſoon become incapable of bearing cold.

30 Expoſure and exerciſe.

In every thing let him be habituated to what is plain and hardy. Let his bed be coarſe and hard, his clothes plain, his fare ſimple. Infants muſt be freely indulged in ſleep: but as Emilius is now advanced beyond infancy, he muſt be accuſtomed at times to go to bed late and get up early, to be ſometimes haſtily waked from ſleep; and thus to prepare himſelf for what he may afterwards have occaſion to ſubmit to in the courſe of life.

As this period is in a particular manner that of exerciſe, and Emilius is encouraged to take as much exerciſe as he chooſes: we muſt endeavour to prompt, but without ſeeming to direct him to ſuch as are moſt proper. Swimming, though not generally attended to, is yet one of the firſt which a boy ought to learn. It may, on many occaſions in life, be of the greateſt advantage, by enabling us to ſave our own life or the life of others. Emilius ſhall be taught to ſwim; he ſhall be taught whatever can really enlarge the ſphere of his power: "could I teach him to fly in the air, I would make him an eagle; if to bear the fire, a ſalamander."

To exerciſe the ſenſes is not merely to make uſe of them; it is to learn to judge by them. Call not your pupil to exert all his ſtrength on every occaſion; but let him learn to judge of the truth of the information which he receives from one ſenſe, by having recourſe to the evidence of another.

It is not impoſſible to improve the ſenſes to a higher degree of perfection than that which they uſually attain. Blind men general poſſeſs the ſenſe of touch in a more exquiſite degree, than we who have alſo eyes to guide and inform us. But they acquire this ſuperior delicacy and acuteneſs of ſenſation, only by their finding it neceſſary to have more frequent recourſe to the information of that ſenſe. Here is then a wide field for improvement and agreeable exerciſe to our pupil.

31 Darkneſs and ghoſts.

What a variety of uſeful diverſions might he be led to entertain himſelf with in the courſe of the night. The hours of darkneſs are generally hours of terror, not only men, but alſo to the brute animals. Even reaſon, knowledge, and courage, are not always ſufficient to render us ſuperior to the terror which darkneſs inſpires.

This timidity is uſually attributed to the tales of ghoſts and goblins with which we are frightened in infancy. But it originates from another cauſe: our ignorance of what is paſſing around us, and our inability to diſtinguiſh objects during that period of darkneſs. The paſſion of fear was implanted by nature in the human breaſt, in order that it might ſerve to put us on our guard againſt danger. But in conſequence of our being ſubject to the influence of that paſſion, when we are ignorant of what ſurrounds us, imagination calls up dangers on all hands. And ſuch is the cauſe from which our terror in darkneſs naturally ariſes.

But the only way to free our pupil from this tyranny of imagination, is to oppoſe to it the power of habit. A bricklayer or tyler is never giddy on looking down from the roofs of houſes. Neither will our pupil be alarmed by the terrors of darkneſs, if he be accuſtomed to go frequently abroad under night. It is eaſy to contrive a number of little amuſements, the agreeableneſs of which may, for a time, overcome our pupil's averſion for darkneſs; and thus may a habit be at length impreſſed.

Let us give yet another inſtance of the means by which children may be led to do what we wiſh, without our impoſing any reſtraint on their will. Suppoſe Emilius is lazy and inactive, and we wiſh to make him learn to run. When walking out with the young ſluggard after dinner, I would ſometimes put a couple of his favourite cakes in my pocket; of theſe each of us ſhould eat one in the courſe of our walk. After ſome time I would ſhow him I had put a third cake in my pocket. This he would not fail to aſk after finſhing his own: no ſays I, I can eat it myſelf, or we will divide it;—or ſtay, we had better let theſe two little boys there run a race for it. Accordingly I propoſe the race to the boys; who readily accept the conditions, and one of them carries off the prize. After ſeeing this ſeveral times repeated, Emilius begins to think himſelf qualified to obtain the third cake as well as any of the little boys, and to look upon running as an accompliſhment of ſome conſequence. He ſeeks an opportunity of being permitted to enter the liſts. He runs; and after being two or three times outſtripped, is at length ſucceſsful, and in a ſhort time attains an undoubted ſuperiority.

32
Drawing.

As children naturally imitate almoſt whatever they behold, they are often diſpoſed to attempt drawing. In this our pupil might be obliged, not merely for the ſake of the art, but to give him a ſteady hand and a good eye. But he ſhould draw from nature, not from other drawings or from prints. Were he to draw the likeneſs of a horſe, he ſhould look at the animal: if to attempt a repreſentation of a houſe, he ſhould view the houſe itſelf. In this method he will, no doubt, ſcratch for a long time without producing any likeneſs: but he will acquire what we propoſed as the ends of his attempting to draw; namely, ſteadineſs of hand and juſtneſs of ſight, by this method, ſooner than by any other.

33
Geometry.

Geometry, when taught in the uſual way, is certainly above the capacity of children; they cannot go along with us in our reaſonings: Yet they are not totally incapable of acquiring even this difficult ſcience; if, when they are proſecuting their amuſements, you lead them inſenſibly to obſerve the properties of the circle, the triangle, and the ſquare, and place them now and then in circumſtances when they may have occaſion to apply their knowledge of theſe to real uſes in life.

A child has been taught the various relations between the outlines, ſurfaces, and contents of bodies, by having cakes ſet before him, cut into all manner of regular ſolids; by which means he was led to maſter the whole ſcience of Archimedes, by ſtudying which form contained the greateſt quantity.

There is a period between infancy and the age of puberty, at which the growth and improvement of our faculties exceed the increaſe of our deſires. About 12 or 13, when the appetite for the ſex has not yet begun to make itſelf felt, when unnatural wants are yet unknown, no falſe appetites yet acquired; at that period, though weak as a man, as a child the youth is ſtrong.

This interval, when the individual is able to effect more than is neceſſary for the gratification of his wiſhes, contains the moſt precious moments of his life, which ought to be anxiouſly filled up in an uſeful manner. This is the beſt time for employment, for inſtruction, for ſtudy.

Now, let us begin to conſider what is uſeful; for, hitherto, we have only inquired what was neceſſary. In entering on our ſtudies, we will make no account of any but ſuch as inſtinct directs us to purſue: thoſe which the pedant and the pretended philoſopher are impelled to purſue ſolely from the deſire of attracting the admiration of mankind, are unworthy of our notice.

The earth which we inhabit, and the ſun by whoſe beams we are enlightened, are the firſt objects which claim our attention. We will therefore direct the attention of our pupil to the phenomena of nature. We will lead him to the knowledge of geography, not by maps, ſpheres, and globes: we will lead Emilius out on ſome beautiful evening to behold the ſetting ſun. Here we take particular notice of ſuch objects as mark the place of his going down. Next morning we viſit the ſpot to contemplate the riſing of the glorious luminary. After contemplating for ſome time the ſucceſſive appearances which the ſcene before us aſſumes, and making Emilius obſerve the hills and the other ſurrounding objects, I ſtand ſilent a few moments, affecting to be occupied in deep meditation: At laſt I addreſs him thus: "I am thinking, that when the ſun ſet laſt night, it went down yonder; whereas this morning you ſee he is riſen on the oppoſite of the plain here before us. What can be the meaning of this?" I ſay nothing more at this time, but rather endeavour to direct his attention to other objects.

This is our firſt leſſon on coſmography.

Our laſt obſervation was made about Midſummer; we will next view the riſing ſun on ſome fine morning in the middle of winter. This ſecond obſervation ſhall be made on the very ſame ſpot which we choſe for the former. When Emilius and I perceive the ſun now emerging above the horizon, we are ſtruck at the change of the place of his riſing. By ſuch leſſons as theſe may the pupil be gradually taught a real, not a ſeeming, acquaintance with the relative motions of the ſun and the planets and with geography.

34
Objects during the ſecond period of childhood.

During the firſt period of childhood, the great object of our ſyſtem of education was to ſpend our time as idly as poſſible, in order that we might avoid employing it to an ill purpoſe: but our views are now changed with our pupil's progreſs in life; and we have ſcarce enough of time for the accompliſhment of our neceſſary purſuits. We therefore proceed as quickly as poſſible in making ourſelves acquainted with the nature of the bodies around us, and the laws by which their motions and appearances are regulated. We keep to this ſtudy at preſent, as being neceſſary for the moſt important purpoſes in life, and as being the moſt ſuitable to the preſent ſtate of our pupil's powers. We ſtill begin with the moſt common and obvious phenomena of nature, regarding them as mere facts; and, advancing from theſe, we come to generalize by degrees.

As ſoon as we are ſo far advanced as to be able to give our pupil an idea of what is meant by the word *uſeful*, we have attained a conſiderable influence over his future conduct. On every occaſion after this, a frequent queſtion between us will be, Of what uſe is this? This ſhall be the inſtrument by means of which I ſhall now be able to render him abſolutely ſubmiſſive to my wiſhes. However, I will allow him to make uſe of it in his turn, and will be careful not to require of him to do or learn any thing the utility of which he cannot comprehend.

35
Robinſon Cruſoe.

Books only teach people to talk about what they do not underſtand. Emilius ſhall have as little recourſe as poſſible to books for inſtruction. Yet if we can find a book in which all the natural wants of man are diſplayed in a manner ſuitable to the underſtanding of a child, and in which the means of ſatisfying thoſe wants are gradually diſplayed with the ſame eaſe and ſimplicity; ſuch a book will be worthy of his moſt attentive ſtudy. There is ſuch a book to be found; but it is neither Ariſtotle, nor Pliny, nor Buffon; it is Robinſon Cruſoe. Emilius ſhall have the adventures of Robinſon put into his hands: he ſhall imitate his example; even affect his dreſs; and, like Robinſon, learn to provide for himſelf without the aid of others.

Another employment of Emilius at this period ſhall be, to viſit the ſhops of various artiſans; and when he enters a ſhop, he ſhall never come out without lending a hand to the work, and underſtanding the nature and the reaſon of what he ſees going forward.

Still, however, we are careful to afford not a hint concerning thoſe ſocial relations the nature of which he is not yet able to comprehend.

The value and importance of the various arts are ordinarily eſtimated, not according to their real utility, but by a very injudicious mode of eſtimation: Thoſe which contribute in a particular manner to the gratification of the fantaſtic wiſhes of the rich, are preferred to thoſe which ſupply the indiſpenſable neceſſaries of life. But Emilius ſhall be taught to view them in a different light. Robinſon Cruſoe ſhall teach him to value the ſtock of a petty ironmonger above that of the moſt magnificent toy-ſhop in Europe. Let us eſtabliſh it as a maxim, that we are to lead our pupil to form juſt notions of things for himſelf, not to dictate to him ours. He will eſtimate the works both of nature and art by their relation to his own convenience; and will therefore regard them as more precious than gold—a ſhoemaker or a maſon, as a man of more importance than the moſt celebrated jeweller in Europe.

The intercourſe of the arts conſiſts in the reciprocal exchange of induſtry; that of commerce, in the exchange of commodities; and that of money, in the exchange of bills and caſh. To make our pupil comprehend the nature of theſe, we have now only to generalize and extend to a variety of examples thoſe ideas of the nature of property, and of the exchange of property, which we formerly communicated to him. The nature of money, as bearing only a conventional valve, which it derives from the agreement of men to uſe it as a ſign for facilitating commerce, may be now explained to Emilius, and will be eaſily comprehended by him. But go no farther: ſeek not yet to explain to the child in what manner money has given riſe to the numerous chimeras of prejudice and caprice; nor how countries which abound moſt in gold and ſilver, come to be the moſt deſtitute of real wealth.

Still our views are directed to bring up our pupil in ſuch a manner that he may be qualified to occupy any place in the order of ſociety into which even the caprice of fortune can throw him. Let us make him a man; not a ſlave, a lord, or a monarch. How much ſuperior the character of a king of Syracuſe turned ſchoolmaſter at Corinth, of a king of Macedon become a notary at Rome, to an unhappy Tarquin incapable of ſupporting himſelf in a ſtate of independence when expelled from his kingdom!

36
The propriety of making a young man in whatever ſphere of life, learn a trade.

Whatever be our ſituation in the world, we can contribute nothing but our perſonal abilities to ſociety. To exert them is therefore the indiſpenſable duty of every one who enjoys the advantages of a ſocial ſtate; and to cultivate them in our pupil to the beſt purpoſe, ought to be the great aim of every courſe of education. Emilius has already made himſelf familiar with all the labours of huſbandry; I can therefore bid him cultivate the land which he inherits from his father. But if it ſhould be loſt, what ſhall be his reſource? He ſhall learn a trade, that he may be provided againſt ſuch an accident. And he ſhall not be a politician, a painter, a muſician, or an architect; to gain employment for his talents in any of theſe arts, would coſt him no leſs trouble than to regain his loſt eſtate. He ſhall learn ſome ſimple mechanical art: he will then need only to ſtep into the firſt ſhop he ſees open, to perform his day's labour, and receives his wages.

It may be here proper to take notice of a miſtake into which people generally fall in determining the trade or profeſſion in which they are to place their children. Some accident diſpoſes the child to declare himſelf for a particular employment: the parent regards that as the employment to which his talents are fitted by the deſign of nature; and permits him to embrace it without inquiring whether another would have been more ſuitable or advantageous. But becauſe I am pleaſed with my occupation, I am not on that account neceſſarily qualified for it. Inclinations do not confer abilities. It requires more careful and accurate obſervation than is generally imagined, to diſtinguiſh the particular taſte and genius with which nature has endowed the mind of a child. We view him careleſsly, and of conſequence we are apt to miſtake caſual inclination for original diſpoſition.

But Emilius needs not now to heſitate about the occupation which he is to chooſe. It is to be ſome mechanical employment. All the diſtinction we have now to make is, to prefer one that is cleanly and not likely to be injurious to his health. We ſhall make choice of that of a joiner. We cannot dedicate all our time to the trade; but at leaſt for two days in the week we will employ ourſelves in learning our trade. We will have no workſhop erected for our convenience, nor will we have a joiner to wait on us in order to give us the neceſſary inſtructions: but for the two days in every week which we dedicate to the purpoſe of learning a trade, we will go to our maſter's workſhop; we will riſe before him in the morning; work according to his orders; eat at his table; and, after doing ourſelves the honour of ſupping with his family, return to our own hard mattreſſes at night. We ſhall be treated only according to the merit of our performances. Our maſter ſhall find fault with our work when clumſily or negligently done, and be pleaſed with it only when well executed.

37
New ideas ſuggeſted to Emilius by his application to a trade.

While my pupil has been accuſtomed to bodily exerciſe and manual labour, his education has been hitherto conducted in ſuch a manner as to give him inſenſibly a taſte for reflection and meditation. Before he has been long a workman, therefore, he will begin to become more ſenſible of that inequality of ranks which takes place in the order of ſociety. He will therefore take notice of his own dependence, and of my apparent wealth, and will be deſirous to know why I contribute not my perſonal exertions to ſociety. I put off the queſtion with telling him, that I beſtow my ſuperfluous wealth on him and the poor; and will take to make a bench or table every week, that I may not be quite uſeleſs to the public.

And now, when about to enter the moſt critical period of life, when juſt on the brink of that age at which the heart and blood begin to feel the impulſe of

38
Progreſs that Emilius has made before the age of puberty.

a new appetite, what progreſs has our pupil made? what knowledge has he acquired? All his ſcience is merely phyſical. Hitherto he has ſcarce acquired any ideas of moral relations; but the eſſential relations between men and things he has attentively ſtudied. He knows the general qualities of certain bodies; but upon thoſe qualities he has not attempted to reaſon. He has an idea of abſtract ſpace by means of geometrical figures; of abſtract quantity, by means of algebraical ſigns. He has no deſire to find out the eſſence of things; their relations alone intereſt him. He values nothing external but from its relation to himſelf. The general conſent of mankind, or the caprice of cuſtom, have not yet given any thing a value in his eyes; utility alone is his meaſure of eſtimation. He is laborious, temperate, patient, reſolute, and bold. His imagination never exaggerates danger. He ſcarce knows as yet what death is; but ſhould it approach him, he is prepared to ſubmit to neceſſity. He is virtuous in every thing relative merely to himſelf. He is prepared to become a virtuous member of ſociety as ſoon as he ſhall be made acquainted with the nature of his ſocial relations. He is free from vice and error as far as is poſſible for human nature. He conſiders himſelf as unconnected with others; requires nothing from any perſon, and thinks none has a right to require any thing of him. Sure a youth arrived thus at his fifteenth year has not miſpent the period of his infancy.

39
New meaſures to be adopted in his education at that age.

But now our pupil has reached the moſt critical period of life. He now feels the influence of the paſſion for the ſex; and as ſoon as we become ſubject to the influence of that paſſion, we are no longer unſocial beings. The want of a miſtreſs ſoon produces the want of a friend.

As hitherto we have been careful not to force or anticipate nature, ſo even now our attention muſt be directed to divert the impulſes of that dangerous appetite which now begins to make itſelf felt. To confine the growing paſſions within proper limits, let it be our care to defer as long as poſſible the time at which they begin to diſplay themſelves. For this purpoſe, let us cautiouſly guard our words and actions in the preſence of our pupil. Let us be careful to give him no premature inſtructions.

To excite and cheriſh that ſenſibility of mind which now firſt begins to ſhow itſelf, to extend the care of the youth beyond himſelf, and to intereſt him in the welfare of his fellow creatures, let us be careful to put ſuch objects in his way as have a tendency to call forth and refine the feelings. It is not poſſible for the human heart to ſympathize with thoſe who are happier than ourſelves: our ſympathy is moved only by the ſight of miſery. We pity in others only thoſe diſtreſſes to which we ourſelves are liable; and our pity for the misfortunes of others is meaſured, not by the quantity of the evil, but by the ſuppoſed ſenſibility of the ſufferer. Let theſe obſervations ſerve to direct us in what manner we are to form the minds of children to humanity and compaſſion.

In proſecution of our deſign, to retard rather than accelerate the growth of the paſſions, let us, when that critical period which we have ſo much feared comes on, ſeclude him as much as poſſible from the intercourſe of ſociety, where ſo many objects appear to inflame the appetites. Let us be circumſpect in the choice of his companions, his employment, his pleaſures. Let all our care be directed to nouriſh his ſenſibility without inflaming his deſires. As his moral powers now begin to unfold themſelves; in cultivating them let us proceed not by way of lecture, or by directing his attention to books, but ſtill by leading him to acquire experience. At length the period will arrive for communicating to him ſome religious inſtruction. When he knows the nature of his relations to ſociety, he may be informed of his relation to, and dependence upon, a Deity.

[The creed of the Savoyard curate, containing thoſe ſentiments concerning religious matters which Rouſſeau ſeems to propoſe as the moſt proper to be inculcated on his pupil, comes next in the order of the work; but it does not appear to be ſo cloſely connected with the ſubject of education as to render it proper for us to give a view of it in this place. The ſentiments which he there advances, the reaſonings which he urges, are evidently hoſtile to revealed religion; and the power of his eloquence has adorned ſlight and ſuperficial arguments with ſuch a charm, that even the ſterneſt believer, if not abſolutely deſtitute of taſte and feeling, muſt read them with delight.]

And now, notwithſtanding all my arts, I can no longer keep back that moment which I have endeavoured to defer to as late a period as poſſible. As ſoon as I perceive that it has certainly arrived, I no longer treat Emilius as my pupil or diſciple, but as my friend. His affections are now expanded beyond himſelf; his moral powers have begun to exert themſelves, and have received ſome cultivation; he alſo is become capable of religious ſentiments, and inſtructed in the nature of his relation to a ſupreme Being. Beſides, it is now requiſite, if we conſider the period to which nature has conducted him, that he ſhould no longer be treated as a ſimple child. Hitherto ignorance has been his guardian, but now he muſt be reſtrained by his own good ſenſe.

Now is the time for me to give him in my accounts; to ſhow him in what manner his time and mine have been employed; to acquaint him with his ſtation and mine, with our obligations to each other, his moral relations, the engagements he has entered into with regard to others, the degree of improvement which he has attained, the difficulties he will hereafter meet with, and the means by which he may ſurmount them; —in a word, to point out to him his critical ſituation, and the new perils which ſurround him; and to lay before him all the ſolid reaſons which ſhould engage him to watch with the utmoſt attention over his conduct, and to be cautious of indulging his youthful deſires.

40
Means employed to preſerve the purity of his manners.

Books, ſolitude, idleneſs, a ſedentary and effeminate life, the company of women and young people, are what he muſt carefully avoid at this age. He has learned a trade, he is not unſkilled in agriculture; theſe may be means, but not our only means, for preſerving him from the impulſe of ſenſual deſire. He is now too familiar with theſe; he can exerciſe them without taking the trouble to reflect; and while his hands are buſy, his head may be engaged about ſomething quite different from that in which he is employed. He muſt have ſome new exerciſe which may at once fix his attention and cauſe him to exert his bodily powers.

powers. We can find none more ſuitable for this purpoſe than hunting. Now, therefore, Emilius ſhall eagerly join in the chaſe; and though I do not wiſh him to acquire that cruelty of diſpoſition and ferocity of temper which uſually diſtinguiſh thoſe who dedicate their lives to that barbarous diverſion, yet at preſent it may have the happieſt effects in ſuſpending the influence of the moſt dangerous of paſſions.

When I have now conducted my pupil ſo far; have informed him of what I have done for him, and of the difficulty of his ſituation; and have reſigned my authority into his hands; he is ſo ſenſible of the dangers to which he is expoſed, and of the tender ſolicitude with which I have watched over him, that he ſtill wiſhes to continue under my direction. With ſome feigned difficulty I again reſume the reins. My authority is now eſtabliſhed. I may command obedience; but I endeavour to guard againſt the neceſſity of uſing it in this manner.

To preſerve him from indulging in licentious pleaſures, I let him know that nature has deſigned us for living in a ſtate of marriage, and invite him to go in ſearch of a female companion. I will deſcribe to him the woman whom he is to conſider as worthy of his attachment in the moſt flattering colours. I will array her in ſuch charms, that his heart ſhall be hers before he has once ſeen her. I will even name her: her name ſhall be Sophia. His attachment to this imaginary fair one will preſerve him from all the allurements of unlawful love. Beſides, I take care to inſpire him with ſuch reverence for himſelf, that notwithſtanding all the fury of his deſires, he will not condeſcend to purſue the enjoyments of debauchery. And though I may now ſometimes intruſt him to his own care, and not ſeek to confine him always under my eye; yet ſtill I will be cautious to watch over his conduct with careful circumſpection.

But as Emilius is to be ſhortly introduced to his Sophia, it may perhaps be proper for us to inquire into her character, and in what manner ſhe has been brought up.

41
Diſtinctive characters of the two ſexes.

There is a natural difference between the two ſexes. The difference in the ſtructure of their bodies ſhows them to be deſtined by nature for different purpoſes in life, and muſt neceſſarily occaſion a diſtinction between their characters. It is vain to aſk which of them merits the pre-eminence: each of them is peculiarly fitted to anſwer the views of nature. Woman is naturally weak and timid, man ſtrong and courageous; the one is a dependent, the other a protector. As the guardian of her virtue, and a reſtraint on her deſires, woman is armed with native modeſty. Reaſon is the guide and governor of man. When a man and a woman are united by conjugal vows, a violation of thoſe vows is evidently more criminal in the woman than in the man. The wife ought to be anſwerable for the genuineneſs of the offpring with which ſhe has been intruſted by nature. It is no doubt barbarous and wicked for the huſband to defraud his wife of the only reward which ſhe can receive for the ſevere duties of her ſex: but the guilt of the faithleſs wife is ſtill more atrocious; and the conſequences of her infidelity are ſtill more unhappy.

But if nature has eſtabliſhed an original diſtinction between the characters of the two ſexes; has formed them for different purpoſes, and aſſigned them different duties; it muſt follow, that the education of the one ſex ought to be conducted in a manner different from that of the other. The abilities common to the two ſexes are not equally divided between them; but if that ſhare which nature has diſtributed to woman be ſcantier than what ſhe has beſtowed on man, yet the deficiency is more than compenſated by the qualities peculiar to the female. When the woman confines herſelf to aſſert her proper rights, ſhe has always the advantage over man; when ſhe would uſurp thoſe of the other ſex, the advantage is then invariably againſt her.

But we require not that woman ſhould be brought up in ignorance. Let us conſider the delicacy of her ſex, and the duties which ſhe is deſtined to perform; and to theſe we may accommodate the edcaution which we beſtow upon her. While boys like whatever is attended with motion and noiſe, girls are fond of ſuch decorations as pleaſe the eye. Dolls are the favourite plaything of the ſex in their infant years. This is an original taſte, of the exiſtence of which we have the plaineſt evidence. All therefore that we ought to do is, to trace and bring it under proper regulation. Allow the girl to decorate her baby in whatever manner ſhe pleaſes; while employed about that, ſhe will acquire ſuch ſkill and dexterity in thoſe arts which are peculiar to her ſex, that with ſcarce any difficulty ſhe will acquire needle work, embroidery and the art of working lace. Her improvements may even be extended as far as deſigning, an art ſomewhat connected with taſte in dreſs; but there is no reaſon that their ſkill in this art ſhould be carried farther than to the drawing of foliage, fruits, flowers, drapery, and ſuch parts of the art as bear ſome relation to dreſs. Always aſſign reaſons for the employment which you give to young girls, but be ſure you keep them conſtantly buſy. They ought to be accuſtomed to laborious induſtry, as well as to bear the abridgement of their liberty. Uſe every art to prevent their work from becoming diſagreeable to them. For that purpoſe, let the mother be careful to make herſelf agreeable. A girl who loves her mother or her aunt, will work cheerfully by them all day; while ſhe to whom her mother is not dearer than all the world beſides, ſeldom turns out well. Never ſuffer girls, even at their diverſions, to be entirely free from reſtraint, nor allow them to run from one amuſement to another. If you now and then detect your daughter uſing a little artifice to excuſe herſelf from obedience, reflect that artifice is, in a certain degree, natural to the fair ſex; and as every natural inclination, when not abuſed, is upright and good, why ſhould it not be cultivated? In order to give girls proper notions of dreſs, let them be taught to conſider ſplendour and elegance of dreſs, as deſigned only to conceal the natural defects of the perſon; and to regard it as the nobleſt triumph, the higheſt praiſe, of beauty, to ſhine with unborrowed luſtre in the ſimpleſt attire. Forbid not young women to acquire thoſe arts which have a tendency to render them agreeable. Why refuſe them the indulgence of learning to dance, to ſing, and to ſtudy ſuch other accompliſhments as afterwards enable them to entertain their huſbands? Girls are more diſpoſed to prattle, and at an earlier age, than boys. We may now and then find it neceſſary to reſtrain their volubility. But the proper queſtion to them on ſuch occaſions is not, as to boys, *Of what uſe is this?* but, *What effects will this produce?* At this early period, when they are yet ſtrangers to the diſtinction between good and evil, and therefore unable to form a juſt judgment concerning any perſon's conduct, we ought to reſtrain them carefully from ſaying what may be diſagreeable to thoſe with whom they converſe.

Girls are no leſs incapable than boys of forming diſtinct notions of religion at an early age. Yet, and even for that very reaſon, religious inſtruction ſhould be communicated to them much ſooner than to the youth of the other ſex. Were we to wait the period when their mental faculties arrive at maturity, we might perhaps loſe the happieſt time, from our inability to make a right diſtinction. Since a woman's conduct is ſubject to public opinion, her belief ought therefore to depend, not on reaſon, but on authority. Every girl ought to follow the religion of her mother, every married woman that of her huſband. They cannot derive a rule of faith from their own inquiry. Let us therefore ſeek, not ſo much to inſtruct them in the reaſons of our belief, as to give them clear diſtinct notions of thoſe articles which we require them to believe. Be more careful to inſtruct her in thoſe doctrines which have a connexion with morality, than in thoſe myſterious articles which we are required to believe, though we cannot comprehend them.

Such are the principles on which the education of Emilius's unknown miſtreſs has been conducted.

[Notwithſtanding the merit of that part of this treatiſe in which the author entertains us with the courtſhip between his Emilius and Sophia, it does not appear to be intimately connected with the ſubject of education as to render it proper for us to preſent our readers with a view of it. We therefore paſs over the courtſhip, to give a view of our author's ſentiments concerning the advantages to be derived from travelling, and the manner in which it ought to be directed.]

42 Emilius attached to a miſtreſs.

43 Travel.

When Emilius has formed a firm attachment to Sophia, and by his aſſiduities has been ſo fortunate as to gain her affections, his great wiſh now is, to be united with her in the bonds of marriage. But as he is ſtill young, is but imperfectly acquainted with the nature of thoſe duties incumbent on him as a member of a particular ſociety, and is even ignorant of the nature of laws and government, I muſt ſeparate him from his Sophia, and carry him to gain a knowledge of theſe things, and of the character and circumſtances of mankind, in various countries, and under various forms of civil government, by travelling. Much has been ſaid concerning the propriety of ſending young people to travel, in order to complete their education. The multiplicity of books is unfavourable to real knowledge. We read with avidity, and think that by reading we render ourſelves prodigiouſly wiſe. But we impoſe on ourſelves: the knowledge which we acquire from books is a falſe ſpecies of knowledge, that can never render us truly wiſe.

To obtain real knowledge, you muſt obſerve nature with your own eyes, and ſtudy mankind. But to gain this knowledge by travelling, it is not neceſſary that we ſhould traverſe the univerſe. Whoever has ſeen ten Frenchmen has beheld them all; and whoever has ſurveyed and compared the circumſtances and manners of ten different nations may be ſaid to know mankind.

To pretend that no advantages may be derived from travelling, becauſe ſome of thoſe who travel return home without having gained much real improvement, would be highly unreaſonable. Young people who have had a bad education, and are ſent on their travels without any perſon to direct or ſuperintend their conduct, cannot be expected to improve by viſiting foreign countries. But they whom nature has adorned with virtuous diſpoſitions, and have been ſo happy as to receive a good education, and go abroad with a real deſire of improvement, cannot but return with an increaſe of virtue and wiſdom. In this manner ſhall Emilius conduct his travels. To induce him to improve in the moſt attentive manner that time which he ſhould ſpend in travelling, I would let him know, that as he had now attained an age in which it might be proper for him to form ſome determination with regard to the plan of his future life, he ought therefore to look abroad into the world, to view the various orders in ſociety, to obſerve the various circumſtances of mankind under different forms of government, and in different parts of the globe; and to chooſe his country, his ſtation, and his profeſſion. With theſe views ſhould Emilius ſet out on his travels: and with theſe views, in the courſe of our travels, we ſhould inquire into the origin of ſociety and government, into the nature of thoſe principles by means of which men are united in a ſocial ſtate, into the various circumſtances which have given riſe to ſo many different forms of government, and into the neceſſary relation between government and manners. Our ſtay in the great towns ſhould be but ſhort: for as in them corruption of manners has riſen to a great height, and diſſipation reigns, a long ſtay in any great town might be fatal to the virtuous diſpoſitions of Emilius. Yet his attachment to Sophia would alone be ſufficient to ſave him from the dangers to which his virtue is expoſed. A young man muſt either be in love, or be a debauchee. Inſtances may be pointed out in which virtue has been preſerved without the aid of love; but to ſuch inſtances I can give little credit.

44 Return from his travels, and marriage.

Emilius, however, may now return to his Sophia. His underſtanding is now much more enlightened than when he ſet out on his travels. He is now acquainted with ſeveral forms of government, their advantages and defects, with the characters of ſeveral different nations, and with the effects which difference in circumſtances may be expected to produce on the characters of nations. He has even been ſo fortunate as to get acquainted with ſome perſons of merit in each of the countries which he has viſited. With theſe advantages gained, and with affection unchanged and unabated, he returns to his Sophia. After having made him acquainted with the languages, the natural hiſtory, the government, the arts, cuſtoms, and manners, of ſo many countries, Emilius eagerly informs me that the period which we had deſtined for our travels is now expired. I aſk, What are then his purpoſes for life? He replies, that he is ſatisfied with the circumſtances in which nature has placed him, and with my endeavours to render him independent on fortune, and wiſhes only for his Sophia to be happy. After giving him a few advices

advices for the regulation of his conduct in life, I conduct him to his Sophia, and behold him united with her in marriage. I behold him happy; with affectionate gratitude he bleſſes me as the author of his happineſs; and I thus receive the reward of all the pains with which I have conducted his education.

45 Remarks. Such are the outlines of the ſyſtem of education propoſed by this ſingular and original genius. For originality of thought, affecting ſentiment, enchanting deſcription, and bold vehement eloquence, this book is one of the nobleſt pieces of compoſition, not only in the French language, but even in the whole compaſs of ancient and modern literature. The irregularity of his method, however, renders it a very difficult taſk to give an abridged view of his work. He conducts his pupil, indeed, from infancy to manhood: But inſtead of being barely a ſyſtem of education, his work is beſides a treaſure of moral and philoſophical knowledge. He has choſen a path, and follows it from the bottom to the ſummit of the hill: yet whenever a flower appears on the right or left hand, he eagerly ſteps aſide to pluck it; and ſometimes, when he has once ſtepped aſide, a new object catches his eye and ſeduces him ſtill farther. Still, however, he returns. His obſervations are in many places looſely thrown together, and many things are introduced, the want of which would by no means have injured either the unity or the regularity of his work. If we attempt to review the principles on which he proceeds in reprobating the prevalent modes of education, and pointing out a new courſe, his primary and leading one ſeems to be, that we ought to watch and ſecond the deſigns of nature, without anticipating her. As the tree bloſſoms, the flowers blow, and the fruit ripens at a certain period; ſo there is a time fixed in the order of nature for the ſenſitive, another for the intellectual, and another for the moral powers of man to diſplay themſelves. We in vain attempt to teach children to reaſon concerning truth and falſehood, concerning right and wrong, before the proper period arrive: We only confound their notions of things, and load their memories with words without meaning; and thus prevent both their reaſoning and moral powers from attaining that ſtrength and acuteneſs of which they are naturally capable. He attempts to trace the progreſs of nature, and to mark in what manner ſhe gradually raiſes the human mind to the full uſe of all its faculties. Upon the obſervations which he has made in tracing the gradual progreſs of the powers of the human mind towards maturity, his ſyſtem is founded.

As it is impoſſible to communicate to the blind any juſt ideas of colours, or to the deaf of ſounds: ſo it muſt be acknowledged, that we cannot poſſibly communicate to children ideas which they have not faculties to comprehend. If they are, for a certain period of life, merely ſenſitive animals, it muſt be folly to treat them during that period as rational and moral beings. But is it a truth that they are, during any part of life, guided ſolely by inſtinct, and capable only of ſenſation? Or, how long is the duration of that period? Has nature unkindly left them to be, till the age of twelve, the prey of appetite and paſſion? So far are the facts of which we have had occaſion to take notice, concerning the hiſtory of infancy and childhood, from leading to ſuch a concluſion, that to us it appears undeniable that children begin to reaſon very ſoon after their entrance into life. When the material world firſt opens on their ſenſes, they are ignorant of the qualities and relations of ſurrounding objects: they know not, for inſtance, whether the candle which they look at be near or at a diſtance; whether the fire with which they are agreeably warmed may alſo affect them with a painful ſenſation. But they remain not long in this ſtate of abſolute ignorance. They ſoon appear to have acquired ſome ideas of the qualities and relative ſituation of bodies. They cannot, however, acquire ſuch ideas, without exerting reaſoning powers in a certain degree. Appearances muſt be compared, and inferences drawn, before knowledge can be gained. It is not ſenſation alone which informs us of the relative diſtances of bodies; nor can ſenſation alone teach us, that the ſame effects which we have formerly obſerved will be again produced by the ſame cauſe.

But if children appear capable of reaſoning at a very early period, they appear alſo to be at a very early period ſubject to the influence of the paſſions: they are angry or pleaſed, merry or ſad, friends or enemies, even while they hang at the breaſt; inſtead of being ſelfiſh, they are naturally liberal and ſocial. And if we obſerve them with candid attention, we will find that the paſſions do not diſplay themſelves ſooner than the moral ſenſe. As nature has wiſely ordered, that we ſhould not ſee, and hear, and feel, without being able to compare and draw inferences from our perceptions; ſo it is a no leſs certain and evident law of nature, that the paſſions no ſooner begin to agitate the human breaſt, than we become able to diſtinguiſh the beauty and the deformity of virtue and vice. The child is not only capable of gratitude and attachment to the perſon who treats him with kindneſs; he is alſo capable of diſtinguiſhing between gratitude and ingratitude, and of viewing each with proper ſentiments. He cries when you refuſe to gratify his deſires; but he boldly inſiſts that he is injured when you uſe him cruelly or unjuſtly. It is indeed impoſſible to attend to the conduct of children during infancy, without being convinced that they are, even then, capable of moral diſtinctions. So little are they acquainted with artificial language, that we and they do not then well underſtand each other. But view their actions; conſider thoſe ſigns by which nature has taught them to expreſs themſelves. Our limbs, our features, and our ſenſes, are not gradually and by piecemeal beſtowed as we advance towards maturity; the infant body comes not into the world mutilated or defective: why then, in point of mental abilities, ſhould we be for a while brutes, without becoming rational and moral beings till the fulneſs of time be accompliſhed? All the differences between the phenomena of manhood and thoſe of infancy and childhood may be accounted for, if we only reflect, that when children come into the world, they are totally unacquainted with all the objects around them; with the appearances of nature, and the inſtitutions of ſociety; that they are ſent into the world in a feeble ſtate, in order that the helpleſſneſs occaſioned by their ignorance may attract the notice and gain the aſſiſtance of thoſe who are able to help them; and that they attain not full ſtrength in the powers either of mind or body, nor a ſufficient acquaintance with nature, with artificial language, and with the arts and inſtitutions of ſociety, till they arrive at manhood.

Even Rouſſeau, notwithſtanding the art with which he lays down his ſyſtem, cannot avoid acknowledging indirectly, on ſeveral occaſions, that our ſocial diſpoſitions, our rational and our moral powers, diſplay themſelves at an earlier period than that at which he wiſhes us to begin the cultivation of them.

But though the great outlines of his ſyſtem be merely theory, unſupported by facts, nay plainly contradictory to facts; yet his obſervations on the impropriety or abſurdity of the prevalent modes of education are almoſt always juſt, and many of the particular directions which he gives for the conducting of education are very judicious. He is often fanciful, and often deviates from the common road, only to ſhow that he is able to walk in a ſeparate path. Yet why ſhould he be oppoſed with ſo much virulence, or branded with ſo many reproachful epithets? His views are liberal and extenſive: his heart ſeems to have glowed with benevolence: his book contains much obſervation of human actions; diſplays an intimate acquaintance with the motives which ſway the human heart; and if not a perfect ſyſtem for education, is yet ſuperior to what any other writers had before done upon the ſubject. It is ſurely true, that we ourſelves often call forth evil paſſions in the breaſts of children, and impreſs them with bad habits: it is no leſs true that we put books in their hands, and load their memory with words, when we ought rather to direct their attention to things, to the phenomena of nature, and the ſimpleſt arts of life. The form in which he has choſen to communicate his ſentiments on the ſubject of education renders the peruſal of it more pleaſing, and his precepts more plain, than they would otherwiſe have been: it is nearly that dramatic form with which we are ſo much delighted in ſome of the nobleſt compoſitions of the ancients.

After viewing the public eſtabliſhments for education which exiſted in ſome of the moſt renowned ſtates of antiquity; and after liſtening to the ſentiments of the experienced Quinctilian, the learned Milton, the judicious Locke, and the bold fanciful Rouſſeau, on this intereſting ſubject; it may now be proper to lay before the reader our own ſentiments concerning the education of youth under a few diſtinct heads.

Indeed, if we were diſpoſed to give abridgments of all the books which have been written on the ſubject of education, or even to hint at all the various modes which have been recommended by teachers or theoriſts, we might ſwell this article to an amazing ſize: Nay, were we only to take notice of the many elegant and ſenſible writers who have of late endeavoured to call the attention of the public to this ſubject, we might extend it to an immoderate length. A Kames, a Prieſtley, a Knox, a Madame de Sillery, and a Berquin, might well attract and fix our attention. But as, among ſuch a crowd of writers, every thing advanced by each cannot be original; and even of thoſe things which are original, only a certain, and that perhaps even a moderate, proportion, can be juſt and judicious; and as they often either borrow from one another, or at leaſt agree in a very friendly manner, though in ſome things they profeſs a determined hoſtility; therefore we ſhall content ourſelves with having taken notice of four of the moſt reſpectable writers on the ſubject.

In preſenting to our readers the reſult of our own obſervations and reflections, we ſhall throw our thoughts nearly under the following heads. The management of children from their birth till they attain the age of five or ſix; from that period till the age of puberty; and from that age till manhood; private and public education; religion and morals; the languages; natural philoſophy; the education of people of rank and fortune; education of perſons deſigned for a mercantile employment, and for the other humbler occupations in active life not particularly connected with literature; education of the female ſex; foreign travel; knowledge of the world; and entrance into active life. We do not pretend to be able to include under theſe heads every thing worthy of notice in the ſubject of education: but under theſe we will be able to comprehend almoſt every thing of importance that has occurred to us on the ſubject.

I. *On the Management of Infants from the Time of their Birth till they attain the Age of five or ſix.*

The young of no other animal comes into the world in ſo helpleſs a ſtate, or continues ſo long to need aſſiſtance, as that of the human ſpecies. The calf, the lamb, and the kid, are vigorous and lively at the inſtant of their birth; require only, for a very ſhort period, nouriſhment and protection from their reſpective dams; and ſoon attain ſuch degrees of ſtrength and activity as to become entirely independent. The infancy of the oviparous animals is not of longer continuance: And, indeed, whatever department of the animal world we may chooſe to ſurvey, we ſtill find that no ſpecies is ſubject to the ſame ſevere laws as man during the firſt period of life.

46
Man compared to other animals, in reſpect to the helpleſſneſs of infancy.

Yet the character and the views of man are ſo very different from thoſe of the other animals, that a more careful attention to theſe may perhaps induce us to regard this ſeeming ſeverity rather as an inſtance of the peculiar kindneſs of the Author of nature. From every obſervation which has been hitherto made on the powers and operations of the inferior animals, we are led to conſider them as guided and actuated chiefly, if not ſolely, by inſtinct, appetite, and ſenſation: their views extend not beyond the preſent moment; nor do they acquire new knowledge or prudence as they advance in life. But the character of the human race is much more exalted. We have alſo powers and organs of ſenſation, inſtincts and appetites; but theſe are the moſt ignoble parts of our nature: our rational faculties and moral powers elevate us above the brutes, and advance us to an alliance with ſuperior beings. Theſe rational faculties and moral powers render us capable of ſocial life, of artificial language, or art, of ſcience, and of religion. Now, were one of the ſpecies to come into the world full grown, poſſeſſed of that bodily ſtrength and vigour which diſtinguiſhes manhood, his ignorance would ſtill render him inadequate to the duties of life; nay, would even render him unable to procure means for his ſubſiſtence: while his manly appearance would deprive him of the compaſſion and benevolent aſſiſtance of others; and his ſtrength and vigour would alſo render him leſs docile and obedient than is neceſſary, in order that he may receive inſtruction in the duties and arts of life. Again, were the period of infancy as ſhort to the human ſpecies as to the other animals; were we to be no longer ſubjected to a parent's authority, or protected by his care, than the bird or the quadruped; we ſhould be expoſed to the dangers and difficulties of the world before we had acquired ſufficient knowledge or prudence to conduct us through them, before we had gained any acquaintance with the ordinary phenomena of nature, or were able to uſe the language or practiſe the arts of men in a ſocial ſtate.

Since then, it is by the benevolence of nature that we are feeble and helpleſs at our entrance into life, and that our progreſs towards maturity is ſlow and gradual; ſince nature has deſtined us to be for a conſiderable time under the care and authority of our parents; and ſince the manner in which we are managed during that early part of life has ſo important an influence on our future character and conduct: it is therefore incumbent on parents to direct that tenderneſs, which they naturally feel for their offspring, in ſuch a manner as to ſecond the views of nature.

47 Dreſs of infants.

When children come into the world, inſtinct directs them to receive nouriſhment from the breaſt, and to claim attention to their pains and wants by crying. We attend to their ſigns, and ſtrive to render them as eaſy as we can. They are waſhed, clothed with ſuch garments as we think moſt ſuitable, and ſuckled either by their mother or by ſome other woman who is conſidered as proper for the purpoſe. The abſurd mode of ſwaddling up infants in ſuch a manner as to confine them almoſt from all motion, and leave ſcarce a limb at liberty, which has been ſo often exclaimed againſt and repreſented as highly injurious to the ſymmetry and vigour of the human frame, is now almoſt entirely laid aſide; and therefore we need not raiſe our voice againſt it. Still, however, there are certainly too many pins and bandages uſed in the dreſs of infants: theſe are unfavourable to the circulation of the blood, impede the growth, and often occaſion thoſe tears and that peeviſhneſs which we raſhly attribute to the natural ill humour of the poor creatures. Their dreſs ought to be looſe and cool, ſo as to preſs hard on no joint, no vein nor muſcle; and to leave every limb at liberty. If too heavy and cloſe, it may occaſion too copious a perſpiration, and at the ſame time confine the matter perſpired on the ſurface of the ſkin; than which nothing can be more prejudicial to the health of the child. It may alſo, however, be too thin and cool: for as moderate warmth is neceſſary to the vegetation of plants; ſo it is no leſs neceſſary for promoting the growth of animals: and, therefore, though the dreſs of infants ought to be looſe and eaſy, yet ſtill it ſhould be moderately warm.

48 Nurſes.

It is common for mothers in affluent or even in comfortable circumſtances, to forego the pleaſure of nurſing their own children, that they may avoid the fatigues with which it is attended. This practice has long prevailed in various ages and among various nations: it has been often reprobated with all the warmth of paſſion, and all the vehemence of eloquence, as diſhonourable, inhuman, contradictory to the deſigns of nature, and deſtructive of natural affection: yet ſtill it prevails; fathers and mothers are ſtill equally deaf to the voice of nature and the declamations of philoſophers. Indeed, in a luxurious age, ſuch a practice may be naturally expected to prevail. In ſuch an age, they who are poſſeſſed of opulence generally perſuade themſelves, that, to be happy, is to ſpend their time wholly amid diverſions and amuſements, without deſcending to uſeful induſtry, or troubling themſelves about the ordinary duties of life. Influenced by ſuch notions, they think it proper for them to manage their family affairs, and to nurſe and educate their children, by proxy; nay, to do for themſelves nothing that another can perform for them. It is vain to make a ſerious oppoſition to theſe abſurd notions; the falſe views of happineſs, the pride and the indolence produced by luxury, will ſtill be too powerful for us. We muſt not hope to perſuade the mother, that to receive the careſſes, to behold the ſmiles, and to mark the bodily and mental powers of her child in their gradual progreſs towards maturity, would be more than a ſufficient compenſation for all the fatigues which ſhe would undergo in nurſing and watching over him in his infant years. We need not mention, that the mutual affection between a mother and her child, which is partly the effect of inſtinct, depends alſo, in no inconſiderable degree, on the child's ſpending the period of infancy in its mother's arms; and that when ſhe ſubſtitutes another in her place, the child naturally transfers its affection to the perſon who performs to it the duties of a mother. We need not urge theſe, nor the various other reaſons which ſeem to recommend to every mother the province of ſuckling her own children, and watching over their infant years; for we will either not be heard, or be liſtened to with contempt. Yet we may venture to ſuggeſt, that if the infant muſt be committed to a ſtranger, ſome degree of prudence may be employed in ſelecting the perſon to whom he is to be intruſted. Her health, her temper, and her manner of ſpeaking, muſt be attended to. A number of other qualification are alſo to be required in a nurſe: but it is rather the buſineſs of the phyſician to give directions with regard to theſe. If her habit of body be any way unhealthy, the conſtitution of the infant that ſucks her milk cannot but be injured: if her temper be rough or peeviſh, the helpleſs child ſubjected to her power will be often harſhly treated; its ſpirit will be broken, and its temper ſoured: if her pronunciation be inarticulate or too rapid, the child may acquire a bad habit when it firſt begins to exert its vocal organs, which will not be eaſily corrected.

49 Influence of treatment in infancy on the abilities and diſpoſitions.

In the milder ſeaſons of the year, infants ought to be frequently carried abroad. Not only is the open air favourable to health, but the freſhneſs, the beauty, the variety, and the lively colours of the ſcenes of nature, have the happieſt effects on the temper, and have even a tendency to enliven and invigorate the powers of the mind. At this period, the faculties of the underſtanding and the diſpoſitions of the heart generally acquire that particular bias, and thoſe diſtinguiſhing features, which characterize the individual during the future part of his life, as quick or dull, mild or paſſionate; and which, though they be generally attributed to the original conformation of the mind by the hand of nature, yet are owing rather to the circumſtances in which we are placed, and the manner in which we are treated, during the firſt part of life.

When children begin to walk, our fondneſs diſpoſes us to adopt many expedients to aſſiſt them. But theſe ſeem to be improper. It is enough for us to watch over them ſo as to guard them from any danger which they might otherwiſe incur by their firſt attempts to move about. Thoſe who adviſe us not to be too anxious to preſerve children from thoſe ſlight hurts to which they are expoſed from their diſpoſition to activity, before they have acquired ſufficient ſtrength or caution, certainly give a judicious piece of advice which ought to be liſtened to. By being too attentive to them, we teach them to be careleſs of themſelves; by ſeeming to regard every little accident which befals them as a moſt dreadful calamity, we inſpire them with timidity, and prevent them from acquiring manly fortitude. When children begin to liſp out a few words or ſyllables, the pleaſure which we feel at hearing them aim at the uſe of our language, diſpoſes us to liſten to them with ſuch attention as to relieve them from the neceſſity of learning an open diſtinct articulation. Thus we teach them to expreſs themſelves in a rapid, indiſtinct, and heſitating manner, which we often find it difficult, ſometimes even impoſſible, to correct, when they are farther advanced. Would we teach them a plain diſtinct articulation, we ought not only to ſpeak plainly and diſtinctly in their preſence, but alſo to diſregard their queſtions and requeſts, if not expreſſed with all the openneſs and diſtinctneſs of pronunciation of which they are capable.

Man is naturally an imitative animal. Scarce any of our natural diſpoſitions is diſplayed at an earlier period than our diſpoſition to imitation. Children's firſt amuſements are dramatic performances, imitative of the arts and actions of men. This is one proof among others, that even in infancy our reaſoning faculties begin to diſplay themſelves; for we cannot agree with ſome philoſophers that children are actuated and guided ſolely by inſtinct in their attempts at imitation.

However that be, the happieſt uſe might be made of this principle which diſcovers itſelf ſo early in the infant mind. Whatever you wiſh the child to acquire, do in his preſence in ſuch a manner as to tempt him to imitate you. Thus, without ſouring his mind by reſtraint during this gay innocent period of life, you may begin even now to cultivate his natural powers. Were it impoſſible at this time to communicate any inſtruction to the boy, without baniſhing that ſprightly gaiety which naturally diſtinguiſhes this happy age, it would be beſt to think only how he might loſe his time in the leaſt diſadvantageous manner. But this is far from being neceſſary. Even now the little creature is diſpoſed to imitation, is capable of emulation, and feels a deſire to pleaſe thoſe whoſe kindneſs has gained his affection. Even now his ſentiments and conduct may be influenced by rewards when prudently beſtowed, and by puniſhments when judiciouſly inflicted. Why then ſhould we heſitate to govern him by the ſame principles, by which the laws of God and ſociety aſſert their influence on our own ſentiments and conduct? Indeed, the imprudent manner in which children are too generally managed at this early period, would almoſt tempt us to think it impoſſible to inſtruct them, as yet, without injuring both their abilities and diſpoſitions. But this is owing ſolely to the careleſſneſs, ſtupidity, or capricious conduct of thoſe under whoſe care they are placed.

50 Obedience whether, and when, to be exacted.

Is implicit obedience to be exacted of children? and at what period of life ſhould we begin to enforce it? As children appear to be capable both of reaſoning and of moral diſtinctions at a very early age; and as they are ſo weak, ſo inexperienced, ſo ignorant of the powers of ſurrounding bodies, and of the language, inſtitutions, and arts of men, as to be incapable of ſupporting or conducting themſelves without direction or aſſiſtance; it ſeems therefore proper that they be required even to ſubmit to authority. To the neceſſity of nature both they and we muſt on many occaſions ſubmit. But if the will of a parent or tutor be always found ſcarce leſs unalterable than the neceſſity of nature, it will always meet with the ſame reſpectful ſubmiſſive reſignation. It may not perhaps be always proper to explain to children the reaſons for which we require their obedience: becauſe, as the range of their ideas is much leſs extenſive than ours; as they do not well underſtand our language, or comprehend our modes of reaſoning; and as they are now and then under the influence of paſſion and caprice, as well as people who are farther advanced in life; we are therefore likely to fail in making them comprehend our reaſons, or in convincing them that they are well grounded. And as it is proper to exact obedience of children; ſo we ſhould begin to require it as ſoon as they become capable of any conſiderable degree of activity. Yet we muſt not confine them like ſlaves, without allowing them to ſpeak, to look, or to move, but as we give the word. By ſuch treatment we could expect only to render them peeviſh and capricious. It will be enough, at firſt, if we let them know that obedience is to be exacted; and if we reſtrain them only where, if left at liberty, they would be expoſed to imminent danger.

If then, at ſo early a time of life as before the age of five or ſix, it is poſſible to render children obedient, and to communicate to them inſtruction; what arts, or what learning, ought we to teach them at that period? To give a proper anſwer to this queſtion, is no eaſy matter. It ſeems at firſt difficult to determine, whether we ought yet to initiate them in letters. But as their apprehenſion is now quick, and their memory pretty tenacious, there cannot be a more favourable time for this very purpoſe. As ſoon as they are capable of a diſtinct articulation, and ſeem to poſſeſs any power of attention, we may with the greateſt propriety begin to teach them the alphabet. The moſt artful, alluring methods may be adopted to render the hornbook agreeable; or we may uſe the voice of authority, and command attention for a few minutes; but no harſhneſs, no ſeverity, and ſcarce any reſtraint. At the ſame time, it will be proper to allow the little creatures to run much about in the open air, to exerciſe their limbs, and to cultivate thoſe ſocial diſpoſitions which already begin to appear, by playing with their equals.

Such are the thoughts which have ſuggeſted themſelves to us concerning the management of children in mere infancy. What an amiable little creature would the boy or girl be, who were brought up in a manner not inconſiſtent with the ſpirit of theſe few hints? Behold him healthy and vigorous, mild, ſprightly, and cheerful:

ful: He is ſubmiſſive and docile, yet not dull or timid; he appears capable of love, of pity, and of gratitude. His mind is hitherto, however, almoſt wholly uninformed: he is acquainted but with a few of the objects around him; and knows but little of the language, manners, and inſtitutions of men: but he feels the impulſe of an ardent curioſity, and all the powers of his mind are alive and active.

II. *On the Management of Children between the Age of five or ſix and the Age of Puberty.*

At this period it may be proper, not only to exact obedience, and to call the child's attention for a few minutes now and then to thoſe things of which the knowledge is likely to be afterwards uſeful to him: but we may now venture to require of him a regular ſteady application, during a certain portion of his time, to ſuch things as we wiſh him to learn. Before this time it would have been wrong to confine his attention to any particular taſk. The attempt could have produced no other effect than to deſtroy his natural gaiety and cheerfulneſs, to blunt the natural quickneſs of his powers of apprehenſion, and to render hateful that which you wiſhed him to acquire. Now, however, the caſe is ſomewhat different: The child is not yet ſenſible of the advantages which he may derive from learning to read, for inſtance; or even though he were able to foreſee all the advantages which he will obtain by ſkill in the art of reading through the courſe of life; yet is it the character of human nature, at every ſtage of life, to be ſo much influenced by preſent objects in preference to future views, that the ſenſe of its utility alone would not be ſufficient to induce him to apply to it. Even at the age of 12, of 20, of 50; nay, in extreme old age, when reaſon is become very perſpicacious, and the paſſions are mortified; ſtill we are unable to regulate our conduct ſolely by views of utility. Nothing could be more abſurd, therefore, than to permit the child to ſpend his time in fooliſh tricks, or in idleneſs, till views of utility ſhould prompt him to ſpend it in a different manner. No; let us begin early to habituate him to application and to the induſtrious exertion of his powers. By endowing him with powers of activity and apprehenſion, and rendering him capable of purſuing with a ſteady eye thoſe objects which attract his deſires, nature plainly points out to us in what manner we ought to cultivate his earlier years. Beſides, we can command his obedience, we can awaken his curioſity, we can rouſe his emulation, we can gain his affection, we can call forth his natural diſpoſition to imitation, and we can influence his mind by the hope of reward and the fear of puniſhment. When we have ſo many means of eſtabliſhing our authority over the mind of the boy without tyranny or uſurpation; it cannot ſurely be difficult, if we are capable of any moderation and prudence, to cultivate his powers, by making him begin at this period to give regular application to ſomething that may afterwards be uſeful.

51 A knowledge of words and of things muſt be learnt at the ſame time.

And if the boy muſt now begin to dedicate ſome portion of his time regularly to a certain taſk, what taſk will be moſt ſuitable? Even that to which children are uſually firſt required to apply; continue teaching him to read. Be not afraid that his abilities will ſuffer from an attention to books at ſo early an age. Say not that it is folly to teach him words before he have gained a knowledge of things. It is neceſſary, it is the deſign of nature, that he ſhould be employed in acquiring a knowledge of things, and gaining an acquaintance with the vocal and written ſigns by which we denote them, at the ſame time. Theſe are intimately connected; the one leads to the other. When you view any object, you attempt to give it a name, or ſeek to learn the name by which men have agreed to diſtinguiſh it: in the ſame manner, when the names of ſubſtances or of qualities are communicated to us, we are deſirous of knowing what they ſignify. At the ſame time, ſo imperfect is the knowledge of nature which children can acquire from their own unaſſiſted obſervation, that they muſt have frequent recourſe to our aſſiſtance before they can form any diſtinct notions of thoſe objects and ſcenes which they behold. Indeed language cannot be taught, without teaching that it is merely a ſyſtem of ſigns, and explaining what each particular ſign is deſigned to ſignify. If, therefore, language is not only neceſſary for facilitating the mutual intercourſe of men, but is even uſeful for enabling us to obtain ſome knowledge of external nature, and if the knowledge of language has a natural tendency to advance our knowledge of things; to acquaint ourſelves with it muſt therefore be regarded as an object of the higheſt importance: it muſt alſo be regarded as one of the firſt objects to which we ought to direct the attention of children. But the very ſame reaſons which prove the propriety of making children acquainted with thoſe artificial vocal ſigns which we uſe to expreſs our ideas of things, prove alſo the propriety of teaching them thoſe other ſigns by which we expreſs theſe in writing. It is poſſible indeed, nay it frequently happens, that we attempt to inſtruct children in language in ſo improper a manner as to confound their notions of things, and to prevent their intellectual powers from making that improvement of which they are naturally capable; but it is alſo poſſible to initiate them in the art of reading, and in the knowledge of language, with better auſpices and happier effects. The knowledge of language may be conſidered as the key by which we obtain acceſs to all the ſtores of natural and moral knowledge.

52 Confinement, how far proper.

Though we now agree to confine our pupil to a certain taſk, and have determined that his firſt taſk ſhall be to learn to read; yet we do not mean to require that he be confined to this taſk during the greateſt part of the day, or that his attention be ſeriouſly directed to no other object. To ſubject him to too ſevere reſtraint would produce the moſt unfavourable effects on his genius, his temper, and his diſpoſitions. It is in conſequence of the injudicious management of children, while they are ſometimes ſuffered to run riot, and at other times cruelly confined like priſoners or ſlaves; it is in conſequence of this, that we behold ſo many inſtances of peeviſhneſs, caprice, and invincible averſion to all ſerious application at this period of life. But were a due medium obſerved, were reſtraint duly tempered with liberty and indulgence, nothing would be more eaſy than to diſpoſe children to cheerful obedience, and to communicate to them inſtruction at this age. That part of their time which they are left to enjoy at liberty, they naturally dedicate to their little ſports.

The favourite ſports of boys are generally active; thoſe of girls, ſedentary. Of each we may take advantage, to prepare them for the future employments of life. However, neither are the amuſements of boys invariably active, nor thoſe of girls always ſedentary; for as yet, the manners and diſpoſitions of the two ſexes are diſtinguiſhed rather by habit or accident than by nature. The diſpoſition to activity which characterizes children, is no leſs favourable to health than to their improvement in knowledge and prudence; their active ſports have a tendency to promote their growth and add new vigour to their limbs. Perhaps, even at this time, children might be enticed to learn the elements of natural philoſophy and natural hiſtory amid their amuſements and ſports. Birds, butterflies, dogs, and other animals, are now favourite objects of their care; their curioſity is powerfully rouſed by the appearance of any ſtrange object; and many of the ſimpleſt experiments of natural philoſophy are ſo pleaſing, that they cannot fail to attract the attention even of thoſe who are leaſt under the influence of curioſity. Yet it would be improper to inſiſt on their attention to theſe things as a taſk: if we can make them regard them as amuſements, it will be well; if not, we muſt defer them to ſome happier ſeaſon. They might alſo, by proper management, be led to acquire ſome ſkill in the arts. They build mimic houſes, and fill them with ſuitable furniture; they conſtruct little boats, and ſail them; they will fence-in little gardens, and cultivate them; and we even ſee them imitate all the labours of the huſbandman. Such is the pleaſure which man naturally feels in exerting his powers, and in acting with deſign. Let us encourage this diſpoſition. Theſe are the moſt ſuitable amuſements in which they can engage.

53 What books moſt proper.

As the boy's attention to literary objects is ſtill ſuppoſed to be continued, he will ſoon be able to read with ſome correctneſs and facility. It becomes an object of importance, and of no ſmall difficulty, to determine what books are to be put into his hands, and in what manner his literary education is to be conducted. After the child is made acquainted with the names and powers of the letters, with their combination into ſyllables, and with the combination of theſe again into words, ſo that he can read with tolerable facility; it will be proper that the pieces of reading which are put into his hands be ſuch as are deſcriptive of the actions of men, of the ſcenes of external nature, and of the forms and characters of animals. With theſe he is already in ſome degree acquainted; theſe are the objects of his daily attention; beyond them the range of his ideas does not yet extend; and therefore other ſubjects will be likely to render his taſk diſagreeable to him. Beſides, our preſent object is to teach him words: in order to teach him words, we muſt let him know their ſignification; but till he have acquired a very conſiderable knowledge of language, till he have gained a rich fund of ſimple ideas, it will be impoſſible for him to read or to hear with underſtanding on any other ſubject but theſe. And let us not as yet be particularly anxious to communicate to him religious or moral inſtruction, otherwiſe than by our example, and by cauſing him to act in ſuch a manner as we think moſt proper. Our great buſineſs at preſent is, to make him acquainted with our language, and to teach him in what manner we uſe it to expreſs our ideas. By his own obſervation, and by our inſtruction, he will ſoon become capable of comprehending all that we wiſh to communicate: But let us not be too haſty; the boy cannot long view the actions of mankind, and obſerve the economy of the animal and the vegetable world, without becoming capable of receiving both religious and moral inſtruction when judiciouſly communicated.

54 Writing.

As ſoon as the pupil can read and ſpell with tolerable facility, and has acquired ſufficient ſtrength of arm and fingers to hold a pen, it may be proper to initiate him in the art of writing. If this art is not made diſagreeable by the manner in which his application to it is required, he will learn it without difficulty. Children's natural diſpoſition to imitate, particularly whatever depends on manual operation, renders this art peculiarly eaſy and pleaſing to them, when they are not harſhly forced to apply to it, nor ſuffered to get into a habit of performing their taſk with haſte and negligence.

55 Reſtraint.

It requires indeed the moſt cautious prudence, the niceſt delicacy, and the moſt artful addreſs, to prevail with children to give a cheerful and attentive application to any appointed taſk. If you are too ſtern and rigid in enforcing application, you may ſeemingly obtain your object: the child ſits motionleſs, and fixes his eye on his book or copy; but his attention you cannot command; his mind is beyond your reach, and can elude your tyranny; it wanders from the preſent objects, and flies with pleaſure to thoſe ſcenes and objects in which it has found delight. Thus you are diſappointed of your purpoſe; and, beſides, inſpire the child with ſuch averſion both to you and to thoſe objects to which you wiſh him to apply, that perhaps at no future period will he view learning otherwiſe than with diſguſt.

56 Gentleneſs.

Again, gentleneſs, and the arts of inſinuation, will not always be ſucceſsful. If you permit the child to apply juſt when he pleaſes; if you liſten readily to all his pretences and excuſes; in ſhort, if you ſeem to conſider learning as a matter not of the higheſt importance, and treat him with kindneſs while he pays but little attention and makes but ſlow progreſs; the conſequences of your behaving to him in this manner will be ſcarce leſs unfavourable than thoſe which attend imprudent and unreaſonable ſeverity. It is, however, ſcarce poſſible to give particular directions how to treat children ſo as to allure them to learning, and at the ſame time to command their ſerious attention. But the prudent and affectionate parent and the judicious tutor will not always be unſucceſsful; ſince there are ſo many circumſtances in the condition of children, and ſo many principles in their nature, which ſubject them to our will.

57 Arithmetic.

The principles of arithmetic ought to make a part in the boy's education as ſoon as his reaſoning powers appear to have attained ſuch ſtrength and quickneſs that he will be able to comprehend them. Arithmetic affords more exerciſe to the reaſoning powers of the mind than any other of thoſe branches of learning to which we apply in our earlier years: and if the child's attention be directed to it at a proper period, if he be allowed to proceed ſlowly, and if care be taken to make him comprehend fully the principles upon which each particular

particular operation proceeds, it will contribute much to increaſe the ſtrength and the acuteneſs of the powers of his underſtanding.

Where the learned languages are regarded as an object worthy of attention, the boy is generally initiated in them about this time, or perhaps earlier. We have reſerved to a ſeparate head the arguments which occur to us for and againſt the practice of inſtructing children in the dead languages; and ſhall therefore only obſerve in this place, that the ſtudy of them ought not to engroſs the learner's attention ſo entirely as to exclude other parts of education.

58 Practical mathematics.

From arithmetic our pupil may proceed to the practical branches of the mathematics: And in all of theſe, as well as in every other branch of learning, what you teach him will be beſt remembered and moſt thoroughly underſtood, if you afford him a few opportunities of applying his leſſons to real uſe in life. Geometry and geography are two moſt important branches of education; but are often taught in ſuch a manner, that no real benefit is derived from the knowledge of them. The means which Rouſſeau propoſes for initiating young people in theſe and in ſeveral other of the arts and ſciences are excellent; and if judiciouſly applied, could hardly fail of ſucceſs.

While boys are engaged in theſe and in the languages, they may alſo attend to and cultivate the bodily exerciſes; ſuch as dancing, fencing, and horſemanſhip. Each of theſe exerciſes is almoſt abſolutely neceſſary for one who is deſigned to have intercourſe with the world; and beſides, they have a tendency to render the powers of the body active and vigorous, and even to add new courage and firmneſs to the mind.

59 Firſt exerciſes in compoſition.

When our pupil has acquired ſome knowledge of his own and of the learned languages, has gained ſome ſkill in the principles of arithmetic and of practical mathematics, and has received ſome inſtruction in the principles of morality and religion, or even before this time, it will be proper to begin him to the practice of compoſition. Themes, verſions, and letters, the firſt exerciſes in compoſition which the boy is uſually required to perform, none of them ſeems happily calculated for leading him to increaſe his knowledge, or to acquire the power of expreſſing himſelf with eaſe and elegance. Without enlarging on the impropriety or abſurdity of theſe exerciſes, we will venture to propoſe ſomething different, which we cannot help thinking would conduce more effectually to the end in view. It has been already obſerved, that the curioſity of children is amazingly eager and active, and that every new object powerfully attracts their regard: but they cannot view any object without taking notice of its moſt obvious qualities; any animal, for inſtance, without taking notice of its ſhape, its colour, its ſeeming mildneſs or ferocity; and they are generally pretty ready to give an account of any thing extraordinary which they have obſerved. How eaſy then would it be to require them to write down an account of any new object expoſed to their obſervation? The taſk would not be difficult; and every new piece of compoſition which they preſented to us would add ſo much to their knowledge of nature. We might even require ſuch ſpecimens of their accuracy of obſervation and ſkill in language, at times when they enjoyed no opportunities of beholding new or ſurpriſing objects; a tree, a flower, a field, a houſe, an animal, any other ſimple object, ſhould be the ſubject of their exerciſe. After ſome time, we might require them to deſcribe ſomething more various and complex. They might give an account of ſeveral objects placed in a relative ſituation; as, a ſtream, and the vale through which it flows; or, a bird, and the manner in which it conſtructs its neſt; or, of one object ſucceſſively aſſuming various appearances, as the bud, the flower, the apple. Human actions are daily expoſed to their obſervation, and powerfully attract their attention. By and by, therefore, their taſk ſhould be to deſcribe ſome action which had lately paſſed in their preſence. We need not purſue this hint farther; but, if we miſtake not, by theſe means young people might ſooner, and much more certainly, be taught to expreſs themſelves with eaſe and correctneſs in writing, than by any of the exerciſes which they are at preſent cauſed to perform with a view to that. Beſides, they would at the ſame time acquire much more real knowledge. The ſtudy of words would then be rendered truly ſubſervient to their acquiring a knowledge of things.

We cannot deſcend to every particular of that ſeries of education in which we wiſh the boy to be engaged from that period when he firſt becomes capable of ſerious application till he reach the age of puberty. It is not neceſſary that we ſhould, after having given abſtracts of what has been offered to the world by ſo many reſpectable writers on the ſubject.

The few hints which we have thrown out will be ſufficient to ſhow, in general, in what manner we wiſh the youth's education to be conducted during this period. Let the parent and the tutor bear in mind, that much depends on their example, with regard to the diſpoſitions and manners of the youth; and let them carefully ſtrive to form him to gentleneſs, to firmneſs, to patient induſtry, and to vigorous courage; let them, if poſſible, keep him at a diſtance from that contagion with which the evil example of worthleſs ſervants and playfellows will be likely to infect him. Now is the time for ſowing the feeds of piety and virtue: if carefully ſown now, they will ſcarce fail to grow up, and bear fruit in future life.

III. *From Puberty to Manhood.*

This age is every way a very important period in human life. Whether we conſider the change which now takes place in the bodily conſtitution, or the paſſion which now firſt begins to agitate the breaſt, ſtill we muſt regard this as a critical ſeaſon to the youth. The buſineſs of thoſe to whoſe care he is ſtill intruſted, is to watch over him ſo as to prevent the paſſion for the ſex from hurrying him to ſhameful and vicious indulgence, and from ſeducing him to habits of frivolity and indolence; to prevent him from becoming either the ſhameleſs rake, or the trifling coxcomb. Though ſo furious is the impulſe of that appetite which now fires the boſom and ſhoots through the veins of the youth, that to reſtrain him from the exceſſes to which it leads can be no eaſy taſk; yet if his education has been hitherto conducted with prudence, if he is fond of manly exerciſes, active, ſober, and temperate, and ſtill influenced by modeſty and the ſenſe of ſhame; even this may through the bleſſing of heaven be accompliſhed. It is impoſſible to give better directions than thoſe of Rouſſeau for this purpoſe. Let the young man know his ſituation; ſet before him in a ſtriking light the virtue which he may practiſe by reſtraining appetite, and the frightful fatal vices into which he may be hurried. But truſt not to precept, nor to any views which you can lay before him, either of the diſgracefulneſs and the pernicious conſequences of vice, or of the dignity and the happy fruits of virtue. Something more muſt be done. Watch over him with the attention of an Argus; engage him in the moſt active and fatiguing ſports. Carefully keep him at a diſtance from all ſuch company, and ſuch books, as may ſuggeſt to his mind ideas of love, and of the gratification at which it aims. But ſtill all your precautions will not counteract the deſigns of nature; nor do you wiſh to oppoſe her deſigns. The youth under your care muſt feel the impulſe of deſire, and become ſuſceptible of love. Let him then fix his affections on ſome virtuous young woman. His attachment to her will raiſe him above debauchery, and teach him to deſpiſe brutal pleaſures: it will operate as a motive to diſpoſe him to apply to ſuch arts, and to purſue ſuch branches of knowledge, as may be neceſſary for his future eſtabliſhment in the world. The good ſenſe of Rouſſeau on this head renders it leſs neceſſary for us to enlarge on it; eſpecially as we are to treat of ſome articles ſeparately which regard the management of youth at this period.

IV. *Religion and Morals.*

60
At what age the principles of religion may be taught.

In pointing out the general plan of education which appears to us the moſt proper to be purſued in order to form a virtuous and reſpectable member of ſociety, we took but ſlight notice of the important objects of religion and morals. At what period and in what manner, ought the principles of religion and morality to be inſtilled into the youthful mind? It has been before obſerved, that children are capable of reaſoning and of moral diſtinctions even at a very early age. But they cannot then comprehend our reaſonings, nor enter into our moral diſtinctions; becauſe they are ſtrangers to our language, and to the artificial manner in which we arrange our ideas when we expreſs them in converſation or in writing. It follows, then, that as ſoon as they are ſufficiently acquainted with our language, it muſt be proper to communicate to them the principles and precepts of morality and religion. Long before this time, they are diligent and accurate obſervers of human actions. For a ſhort period it is merely the external act which they attend to and obſerve: ſoon, however, they penetrate farther; conſcious themſelves of reflection aud volition, they regard us alſo as thinking beings; conſcious of benevolent and of unfriendly diſpoſitions, they regard us as acting with deſign, and as influenced by paſſion: naturally imitative animals, they are diſpoſed in their conduct to follow the example which we ſet before them. By our example we may teach them piety and virtue long before it can be proper to offer them religious or moral inſtruction in a formal manner.

We cannot preſume to determine at what particular period children ought to be firſt informed of their relations to God and to ſociety, and of the duties incumbent on them in conſequence of thoſe relations. That period will be different to different children, according to the pains which have been taken, and the means which have been employed, in cultivating their natural powers. Perhaps even where the moſt judicious maxims of education have been adopted, and have been purſued with the happieſt effects, it cannot be ſooner than the age of eight or nine. But even before this period much may be done. Show the child your reverence for religion and virtue; talk in his preſence, and in the plaineſt, ſimpleſt terms, though not directly to him, of the exiſtence of God the creator, the preſerver and the governor of the world; ſpeak of the conſtant dependance of every creature on the gracious care of that Being; mention with ardour the gratitude and obedience which we owe to him as our great parent and beſt benefactor; next, ſpeak of the mutual relations of ſociety; of the duties of children and parents, of maſters and ſervants, of man to man. At length, when his mind is prepared by ſuch diſcourſes which have paſſed in his preſence without being addreſſed to him, you may begin to explain to him in a direct manner the leading doctrines of religion. He will now be able to comprehend you, when you addreſs him on that important ſubject: the truths which you communicate will make a powerful impreſſion on his mind; an impreſſion which neither the corruption and diſſipation of the world, nor the force of appetite and paſſion, will ever be able to efface.

61
Habit.

Some writers on this ſubject have aſſerted, that youth are incapable of any juſt ideas of religion till they attain a much more advanced age; and have inſiſted, that, for this reaſon, no attempts ſhould be made to communicate to them the articles of our creed in their earlier years. This doctrine, both from its novelty and from its pernicious tendency, has provoked the keeneſt oppoſition. It has, however, been oppoſed rather with keenneſs than with acuteneſs or ſkill. Its opponents ſeem to have generally allowed that children are incapable of reaſoning and of moral diſtinctions; but they have aſcribed wonderful effects to habit. Enrich the memories of children, ſay they, with the maxims of morality, and with the doctrines of religion; teach them prayers, and call them to engage in all the ordinances of religion. What though they comprehend not the meaning of what they learn? What though they underſtand not for what purpoſe you bid them repeat their prayers, nor why you confine them on the Lord's day from their ordinary amuſements? Their powers will at length ripen, and they will then ſee in what they have been employed, and derive the higheſt advantage from the irkſome taſks to which you confined them. You have formed them to habits which they will not be able to lay aſide: After this they cannot but be religious at ſome period of life, even though you have inſpired them with a diſguſt for the exerciſes of religion. Thoſe good people have alſo talked of the principle of *the aſſociation of ideas*. As no man ſtands alone in ſociety, ſay they; ſo no one idea exiſts in the mind ſingle and unconnected with others: as you are connected with your parents, your children, your friends, your countrymen; ſo the idea of a tree, for inſtance, is connected with that of the field in which it grows, of the fruit which it bears, and of contiguous, diſſimilar, and reſembling objects. When any one ſet of related ideas have been often preſented to the mind in connexion with one another, the mind at length comes to view them as ſo intimately united, that any particular one among them never fails to introduce the reſt. Reviſit the ſcenes in which you ſpent your earlieſt years; the ſports and companions of your youth naturally ariſe to your recollection. Have you applied to the ſtudy of the claſſics with reluctance and conſtraint, and ſuffered much from the ſeverity of parents and tutors for your indifference to Greek and Latin; you will, perhaps, never through the courſe of life ſee a grammar ſchool, without recollecting your ſufferings, nor look on a Virgil or Homer without remembering the ſtripes and confinement which they once occaſioned to you. In the ſame manner, when religious principles are impreſſed on the mind in infancy in a proper manner, a happy aſſociation is formed which cannot fail to give them a powerful influence on the ſentiments and conduct in a future life. But if we have advanced to manhood before being informed of the exiſtence of a Deity, and of our relation to him; the principles of religion, when communicated, no longer produce the ſame happy effects: the heart and the underſtanding are no longer in the ſame ſtate; nor will the ſame aſſociations be formed.

62 Dr Prieſtley's opinion concerning aſſociation of *ideas.*

This doctrine of *the aſſociation of ideas* has been adduced by an ingenious writer, diſtinguiſhed for his diſcoveries in natural philoſophy, and for his labours in controverſial divinity, as an argument in behalf of the propriety of inſtructing youth in the principles of religion even in their earlieſt years. We admire, we eſteem, the ſpirit which has prompted him to diſcover ſo much concern for the intereſts of the riſing generation; but at the ſame time we will not conceal our opinion, that even this argument ought to be urged with caution. Many of the phenomena of human nature may indeed be explained, if we have recourſe to the principle of *aſſociation*. The influence of any principle, religious or moral, depends in a great meaſure on the ideas and images which, in conſidering it, we have been accuſtomed to aſſociate with it in our minds. But what are the ideas or images moſt likely to be aſſociated by children with the doctrines and duties of religion, if we call them to liſten to the one and perform the other at too early a period? Will they be ſuch as may aſſiſt the influence of religion on their ſentiments and conduct in the future part of life? Obſerve the world: Are thoſe who, in infancy, have been moſt rigidly compelled to get their catechiſms by rote, either the moſt pious or the beſt informed in religious matters? Indeed, when we conſider what has been ſaid of the influence of habit, and of the aſſociation of ideas, we cannot help thinking, that any arguments which on the preſent occaſion may be adduced from either of theſe, tend directly to prove, not that we ought to pour in religious inſtruction into the minds of children, without conſidering whether they be qualified to receive it; but, on the contrary, that we ought cautiouſly to wait for and catch the proper ſeaſon;—that ſeaſon when the youthful mind, no longer a ſtranger to our language, our ſentiments, our views of nature, or our manner of reaſoning, will be able to go along with us, when we talk to him of a ſupreme Being, or our condition as dependant and accountable creatures, of truth, benevolence, and juſtice.

We flatter ourſelves, then, that our readers will readily agree with us, 1ſt, That the moral and reaſoning powers of children begin to diſplay themſelves at a very early age, even in infancy. 2dly, That as ſoon as they have made themſelves acquainted with the moſt obvious appearances of nature, and have gained a tolerable knowledge of our language and our manner of arranging our ideas in reaſoning, we may with the greateſt propriety begin to inſtruct them in the principles of religion. 3dly, That the moſt careful and judicious obſervation is neceſſary to enable us to diſtinguiſh the period at which children become capable of receiving religious inſtruction; becauſe, if we either attempt to communicate to them theſe important truths too early, or defer them till towards manhood, we may fail of accompliſhing the great end which we have in view.

If we can be ſo fortunate as to chooſe the happieſt ſeaſon for ſowing the firſt ſeeds of piety in the infant mind, our next care will be to ſow them in a proper manner. We muſt anxiouſly endeavour to communicate the principles of religion and morality, ſo as they may be eaſieſt comprehended by the underſtanding of the learner, and may make the deepeſt impreſſion on his heart. It would be a matter of the greateſt difficulty to give particular directions on this head. The diſcretion of the parent or tutor muſt here be his guide. We are afraid that ſome of the catechiſms commonly taught are not very happily calculated to ſerve the purpoſe for which they are intended. Yet we do not wiſh that they ſhould be neglected while nothing more proper is introduced in their room. In inſtructing children in the firſt principles of religion, we muſt beware of arraying piety in the gloomy garb, or painting her with the forbidding features, in which ſhe has been repreſented by anchorites, monks, and puritans. No; let her aſſume a pleaſing form, a cheerful dreſs, and an inviting manner. Deſcribe the Deity as the affectionate parent, the benefactor, and though the impartial yet the merciful judge of mankind. Exhibit to them Jeſus Chriſt, the generous friend and Saviour of the poſterity of Adam, who with ſuch enchanting benevolence hath ſaid, "Suffer little children to come unto me." Repreſent to them his yoke as eaſy, and his burden as light. Inſiſt not on their ſaying long prayers or hearing tedious ſermons. If poſſible, make the doctrines of religion to appear to them as glad tidings, and its duties as the moſt delightful of taſks.

63 Catechiſms.

V. *The Languages.*

Is the time uſually ſpent in learning the languages uſefully occupied? What advantages can our Britiſh youth derive from an acquaintance with the languages and the learning of Greece and Rome? Would we liſten to many of the fathers, the mothers, and the polite tutors of the preſent age, they will perſuade us, that the time which is dedicated to grammar-ſchools, and to Virgil, Cicero, Homer, and Demoſthenes, is fooliſhly thrown away; and that no advantages

64 Prejudices againſt claſſical education.

advantages can be gained from the ſtudy of claſſical learning. They wiſh their children and pupils to be not merely ſcholars: they wiſh them to acquire what may be uſeful and ornamental when they come to mingle with the world; and for this purpoſe, they think it much better to teach their young people to ſmatter out French, to dance, to fence, to appear in company with invincible aſſurance, and to dreſs in ſuch a manner as may attract the attention of the ladies. Beſides, the tenderneſs and humanity of thoſe people are amazing. They are ſhocked at the idea of the ſufferings which boys undergo in the courſe of a claſſical education. The confinement, the ſtripes, the harſh language, the burdens laid on the memory, and the pain occaſioned to the eyes, during the dreary period ſpent in acquiring a knowledge of Greek and Latin, affect them with horror when they think of them as inflicted on children. They therefore give the preference to a plan of education in which leſs intenſe application is required and leſs ſeverity employed.

65 Prejudices for it.

But, again, there are others who are no leſs warm in their eulogiums on a claſſical education, and no leſs induſtrious in recommending the ſtudy of Greek and Latin, than thoſe are eager in their endeavours to draw neglect on the poliſhed languages of antiquity. With this ſecond claſs, if an adept in Greek and Latin, you are a great and learned man; but without thoſe languages, contemptible for ignorance. They think it impoſſible to inſpire the youthful mind with generous or virtuous ſentiments, to teach the boy wiſdom, or to animate him with courage, without the aſſiſtance of the ancient philoſophers, hiſtorians, and poets. Indeed their ſuperſtitious reverence for the ancient languages, and for thoſe writers whoſe compoſitions have rendered Greece and Rome ſo illuſtrious, leads them to aſcribe many other ſtill more wonderful virtues to a claſſical education.

With which of theſe parties ſhall we join? or ſhall we mediate between them? Is it improper to call youth to the ſtudy of the languages? Is it impoſſible to communicate any uſeful knowledge without them? Or are they, though highly uſeful, yet not always indiſpenſably neceſſary?

66 Utility of claſſical learning towards the improvement of our mother tongue.

We have formerly taken notice of one circumſtance in favour of a claſſical education, to which it may be proper to recal the attention of our readers. We obſerved, that the cultivation of claſſical learning has a favourable influence on the living languages. It has a tendency to preſerve their purity from being debaſed, and their analogy from becoming irregular. In ſtudying the dead languages, we find it neceſſary to pay more attention to the principles of grammar than in acquiring our mother tongue. We learn our native language without attending much to its analogy and ſtructure. Of the numbers who ſpeak Engliſh through the Britiſh dominions, but few are ſkilled in the inflection of its nouns and verbs, or able to diſtinguiſh between adverbs and conjunctions. Deſirous only of making their meaning underſtood, they are not anxious about purity or correctneſs of ſpeech. They reject not an expreſſion which occurs to them, becauſe it is barbarous or ungrammatical. As they grew up they learned to ſpeak from their mothers, their nurſes, and others about them, they were ſoon able to make known their wants, their wiſhes, and their obſervations, in words. Satisfied with this, or called at a very early period to a life of humble induſtry, they have continued to expreſs themſelves in their mother tongue without acquiring any accurate knowledge of its general principles. If theſe people find occaſion to expreſs themſelves in writing, they are ſcarce more ſtudious of correctneſs and elegance in writing than in ſpeaking; or, though they may aſpire after thoſe properties, yet they can never attain them. But ſuch writers or ſpeakers can never refine any language, or reduce it to a regular analogy. Neither can they be expected to diſtinguiſh themſelves as the guardians of the purity and regularity of their native tongue, if it ſhould before have attained a high degree of perfection. But they who, in learning a language different from their native tongue, have found it neceſſary to pay particular attention to the principles of grammar, afterwards apply the knowledge of grammar which they have thus acquired in uſing their mother tongue; and by that means become better acquainted with its ſtructure, and learn to write and ſpeak it with more correctneſs and propriety. Beſides, the languages of Greece and Rome are ſo highly diſtinguiſhed for their copiouſneſs, their regular analogy, and for various other excellencies, which render them ſuperior to even the chief of modern languages, that the ſtudy of them has a natural tendency to improve and enrich modern languages. If we look backwards to the 15th century, when learning began to revive in Europe, and that ſpecies of learning which began firſt to be cultivated was claſſical literature, we find that almoſt all the languages then ſpoken in Europe were wretchedly poor and barbarous. Knowledge could not be communicated, nor buſineſs tranſacted, without calling in the aid of Latin. Claſſical learning, however, ſoon came to be cultivated by all ranks with enthuſiaſtic eagerneſs. Not only thoſe deſigned to purſue a learned profeſſion, and men of fortune whoſe object was a liberal education without a view to any particular profeſſion; but even the lower ranks, and the female ſex, keenly ſtudied the languages and the wiſdom of Greece and Rome. This avidity for claſſical learning was followed by many happy effects. But its influence was chiefly remarkable in producing an amazing change on the form of the living languages. Theſe ſoon became more copious and regular; and many of them have conſequently attained ſuch perfection, that the poet, the hiſtorian, and the philoſopher, can clothe their thoughts in them to the greateſt advantage. Could we derive no new advantage from the ſtudy of the ancient languages, yet would they be worthy of our care, as having contributed ſo much to raiſe the modern languages to their preſent improved ſtate. But they can alſo conduce to the preſervation and ſupport of thoſe noble ſtructures which have been reared by their aſſiſtance. The intercourſe of nations, the affectation of writers, the gradual introduction of provincial barbariſms, and various other cauſes, have a tendency to corrupt and debaſe even the nobleſt languages. By ſuch means were the languages of Greece and Rome gradually corrupted, till the language uſed by a Horace, a Livy, a Xenophon, and a Menander, was loſt in a jargon unfit for the purpoſes of compoſition. But if we would not diſdain to take advantage of them, the claſſical works in thoſe languages might prevent

prevent that which we uſe from experiencing ſuch a decline. He who knows and admires the excellencies of the ancient languages, and the beauties of thoſe writers who have rendered them ſo celebrated, will be the firm enemy of barbariſm, affectation, and negligence, whenever they attempt to debaſe his mother tongue. We venture therefore to aſſert, that when the poliſhed languages of antiquity ceaſe to be ſtudied among us, our native tongue will then loſe its purity, regularity, and other excellencies, and gradually decline till it be no longer known for the language of Pope and of Addiſon; and we adduce it as an argument in behalf of claſſical learning, that it has contributed ſo much to the improvement of the living languages, and is almoſt the only means that can prevent them from being corrupted and debaſed.

67
For inuring to induſtry.

In thoſe plans of education of which the ſtudy of the dead languages does not make a part, proper means are ſeldom adopted for impreſſing the youthful mind with habits of induſtry: nor do the judgment, the memory, and the other powers of the mind, receive equal improvement, as they paſs not through the ſame exerciſes as in a claſſical education. Let us enter thoſe academies where the way to a complete education leads not through the thorny and rugged paths of claſſical literature; let us attend to the exerciſes which the polite teachers cauſe their pupils to perform. Do they inſiſt on laborious induſtry or intenſe application? No; they can communicate knowledge without requiring laborious ſtudy. They profeſs to allow their pupils to enjoy the ſweets of idleneſs, and yet render them prodigies of learning. But are their magnificent promiſes ever fulfilled? Do they indeed cultivate the underſtandings of the young people intruſted to their care? They do not: their care is never once directed to this important object. To adorn them with ſhowy and ſuperficial qualities, is all that thoſe gentlemen aim at. Hence, when their pupils come to enter the world and engage in the duties of active life, they appear deſtitute of every manly qualification. Though they have attained the age and grown up to the ſize of manhood, their underſtandings are ſtill childiſh and feeble: they are capricious, unſteady, incapable of induſtry or fortitude, and unable to purſue any particular object with keen, unremitting perſeverance. That long ſeries of ſtudy and regular application, which is requiſite in order to attain ſkill in the ancient languages, produces much happier effects on the youthful mind. The power of habit is univerſally felt and acknowledged. As he who is permitted to trifle away the earlieſt part of his life in idleneſs or in frivolous occupations, can ſcarce be expected to diſplay any manly or vigorous qualities when he reaches a more mature age; ſo, on the contrary, he whoſe earlier days have been employed in exerciſing his memory and furniſhing it with valuable treaſures, in cultivating his judgment and reaſoning powers by calling the one to make frequent diſtinctions between various objects, and the other to deduce many inferences from the compariſon of the various objects preſented to the underſtanding, and alſo in ſtrengthening and improving the acuteneſs of his moral powers by attending to human actions and characters, and diſtinguiſhing between them, as virtuous or vicious, as mean or glorious: he who has thus cultivated his powers, may be naturally expected to diſtinguiſh himſelf when he comes to perform his part in active life, by prudence, activity, firmneſs, perſeverance, and moſt of the other noble qualities which can adorn a human character. But in the courſe of a claſſical education, the powers of the mind receive this cultivation; and therefore theſe happy effects may be expected to follow from it. The repetitions which are required afford improving exerciſe to the memory, and ſtore it with the moſt valuable treaſures; the powers of the underſtanding are employed in obſerving the diſtinctions between words; in tracing words to the ſubſtances and qualities in nature which they are uſed to repreſent; in comparing the words and idioms of different languages, and in tracing the laws of their analogy and conſtruction; while our moral faculties are at the ſame time improved by attending to the characters which are deſcribed, and the events and actions which are related, in thoſe books which we are directed to peruſe in order to acquire the ancient languages. We aſſert therefore that the ſtudy of the ancient languages is particularly uſeful for improving and ſtrengthening all the powers of the mind: and by that means, for preparing us to act our part in life in a becoming manner; and this our readers will readily agree with us in conſidering as a weighty argument in behalf of that plan of education.

68
Fund of uſeful and elegant knowledge which ancient authors afford.

But if, after all, claſſical learning is ſtill to be given up, where ſhall we find the ſame treaſures of moral wiſdom, of elegance, and of uſeful hiſtorical knowledge, which the celebrated writers of Greece and Rome afford? Will you content yourſelf with the modern writers of Italy, France, and England? Or will you deign to ſurvey the beauties of Homer and Virgil through the medium of a tranſlation? No ſurely; let us penetrate to thoſe ſources from which the modern writers have derived moſt of the excellencies which recommend them to our notice; let us diſdain to be impoſed upon by the whims or the ignorance of a tranſlator.

Juvat integros accedere fontes.

Farther, claſſical learning has long been cultivated among us; and both by the ſtores of knowledge which it has conveyed to the mind, and the habits which it has impreſſed, has contributed in no ſmall degree to form many illuſtrious characters. In reviewing the annals of our country, we will ſcarce find an eminent politician, patriot, general, or philoſopher, during the two laſt centuries, who did not ſpend his earlier years in the ſtudy of the claſſics.

Yet though we have mentioned theſe things in favour of claſſical literature, and were we to deſcend to minute particulars might enumerate many more facts and circumſtances to recommend it; we mean not to argue that it is abſolutely impoſſible to be a wiſe, a great, or a good man, unleſs you are ſkilled in Greek and Latin. Means may, no doubt, be adopted to inſpire the young mind with virtuous diſpoſitions, to call forth the powers of the youthful underſtanding, and to impreſs habits of induſtry and vigorous perſeverance, without having recourſe to the diſcipline of a grammar ſchool. But we cannot help thinking, for the reaſons which we have ſtated to our readers, that a claſſical education is the moſt likely to produce theſe happy effects.

As we are afterwards to take particular notice of the courſe of education moſt ſuitable for thoſe who are to occupy the humble ſtations in ſociety, we ſhall not here inquire whether it be proper to introduce them to an acquaintance with the Greek and Latin claſſics.

VI. *On the Education of People of Rank and Fortune.*

69 Duties of people of rank.

THOSE whom the kindneſs of providence has placed in an elevated ſtation, and in affluent circumſtances, ſo that they ſeem to be born rather to the enjoyment of wealth and honours than to act in any particular profeſſion or employment, have notwithſtanding a certain part aſſigned them to perform, and many important duties to fulfil. They are members of ſociety, and enjoy the protection of the civil inſtitutions of that ſociety to which they belong; they muſt therefore contribute what they can to the ſupport of thoſe inſtitutions. The labours of the induſtrious poor are neceſſary to ſupply them with the luxuries of life; and they muſt know how to diſtribute their wealth with prudence and generoſity among the poor. They enjoy much leiſure; and they ought to know how to employ their leiſure hours in an innocent and agreeable manner. Beſides, as their circumſtances enable them to attract the regard and reſpect of thoſe who are placed in inferior ſtations, and as the poor are ever ready to imitate the conduct of their ſuperiors; it is neceſſary that they endeavour to adorn their wealth and honours by the moſt eminent virtues, in order that their example may have a happy influence on the manners of the community.

70 How to form the temper of a young man of fortune.

Their education ought therefore to be conducted with a view to theſe ends. After what we have urged in favour of a claſſical education, our readers will naturally preſume that we regard it as highly proper for a man of fortune. The youth who is deſtined to the enjoyment of wealth and honours, cannot ſpend his earlier years more advantageouſly than in gaining an acquaintance with the elegant remains of antiquity. The benefits to be derived from claſſical learning are particularly neceſſary to him. Care muſt be taken to preſerve him from acquiring a haughty, fierce, imperious temper. The attention uſually paid to the children of people of fortune, and the fooliſh fondneſs with which they are too often treated, have a direct tendency to inſpire them with high notions of their own importance, and to render them paſſionate, overbearing, and conceited. But if their temper acquire that bias even in childhood, what may be expected when they advance towards manhood, when their attention is likely to be oftener turned to the dignity and importance of that rank which they occupy, and to the pitiful humility of thoſe beneath them? Why, they are likely to be ſo proud, inſolent, reſentful, and revengeful, as to render themſelves diſagreeable and hateful to all who know them: and beſides, to be incapable of thoſe delightful feelings which attend humane, benevolent, and mild diſpoſitions. Let the man of fortune, therefore, as he is concerned for the future happineſs and dignity of his child, be no leſs careful to prevent him from being treated in ſuch a manner as to be inſpired with haughtineſs, caprice, and inſolence, than to prevent his mind from being ſoured by harſh and tyrannical uſage.

The manly exerciſes, as they are favourable to the health, the ſtrength, and even the morals; ſo they are highly worthy of engaging the attention of the young gentleman. Dancing, fencing, running, horſemanſhip, the management of the muſket, and the motions of military diſcipline, are none of them unworthy of occupying his time, at proper ſeaſons. It is unneceſſary to point out the advantages which he may derive from dancing; theſe ſeem to be pretty generally underſtood. Perhaps our men of fortune would be aſhamed to make uſe of their legs for running; but occaſions may occur, on which even this humble accompliſhment may be uſeful. Though we wiſh not to ſee the young man of fortune become a jockey; yet to be able to make a graceful appearance on horſeback, and to manage his horſe with dexterity, will not be unworthy of his ſtation and character. If times of public danger ſhould ariſe, and the ſtate ſhould call for the ſervices of her ſubjects againſt any hoſtile attack, they whoſe rank and fortune place them in the moſt eminent ſtations will be firſt expected to ſtand forth; but if unacquainted with thoſe exerciſes which are connected with the military art, what a pitiful figure muſt they make in the camp, or on the field of battle?

71 Law.

As the man of fortune may perhaps enjoy by hereditary right, or may be called by the voice of his fellow citizens, to a ſeat among the legiſlative body of his country; he ought in his youth to be carefully inſtructed in the principles of her political conſtitution, and of thoſe laws by which his own rights and the rights of his fellow citizens are determined and ſecured.

72 Philoſophy.

Natural philoſophy, as being both highly uſeful and entertaining, is well worthy of the attention of all who can afford to appropriate any part of their time to ſcientific purſuits; to the man of fortune, a taſte for natural philoſophy might often procure the moſt delightful entertainment. To trace the wonders of the planetary ſyſtems, to mark the proceſs of vegetation, to examine all the properties of that fine element which we breathe, to trace the laws by which all the different elements are confined to their proper functions, and above all to apply the principles of natural philoſophy in the cultivation of the ground, are amuſements which might agreeably and innocently occupy many of the leiſure hours of the man who enjoys a ſplendid and independent fortune.

73 Hiſtory and morals.

Neither do we ſuppoſe civil hiſtory and the principles of morals to be overlooked. Without being acquainted with theſe, how could any juſt or accurate knowledge of the laws and political conſtitution of his country be acquired by the young gentleman? Hiſtory expoſes to our obſervation the fortune and the actions of other human beings, and thus ſupplies in ſome meaſure the place of experience; it teaches prudence, and affords exerciſe to the moral ſenſe. When hiſtory condeſcends to take notice of individuals, they are almoſt always ſuch as have been eminent for virtue, for abilities, or for the rank which they held in life; to the rich and great it ought to ſpeak with peculiar efficacy, and they ought to be carefully invited to liſten to its voice.

Such then is the manner in which we wiſh the education of young men of rank and fortune to be conducted.

ducted, in order that they may be prepared for enjoying their opulence and honours with becoming dignity. Let them be early inured to habits of vigorous induſtry and perſevering firmneſs, by paſſing through a regular courſe of claſſical learning in a free ſchool; let them play and converſe with their equals, and not be permitted to form high ideas of their own importance, nor to domineer over ſervants or inferiors: Let them be carefully inſtructed in the principles of morality and religion: Let them be taught the manly exerciſes: Let them be carefully informed of the nature of the political conſtitution of their country, and of the extent of thoſe civil and political rights which it ſecures to them and their fellow citizens: Let them be called to trace the annals of mankind through the records of hiſtory; to mark the appearances and operations of nature, and to amuſe themſelves by purſuing theſe to their general cauſes. We ſay nothing of cauſing the young man of fortune to learn ſome mechanical art: We think ſkill in a mechanical art might now and then afford him an innocent and pleaſing amuſement; but we do not conſider it as abſolutely neceſſary, and therefore do not inſiſt on his acquiring it. With thoſe accompliſhments we hope he might become an uſeful member of ſociety, might adorn the rank and fortune to which he is born, and might find wealth and high ſtation a bleſſing, not a curſe. It is peculiarly unfortunate for our age and country, that people of rank and fortune are not ſo ſtudious that their children acquire theſe as the more ſuperficial accompliſhments.

VII. *On the Education of People deſigned for a Mercantile Employment, and for the humbler Occupations in Life not particularly connected with Literature.*

74 Elegant literature.

WERE modern literature in a leſs flouriſhing ſtate; were the Engliſh and French languages adorned with fewer eminent poetical, hiſtorical, and philoſophical compoſitions; we might perhaps inſiſt on it as neceſſary to give the boy, who is deſigned for a mercantile employment, a claſſical education. At preſent this does not appear abſolutely neceſſary; yet we do not preſume to forbid it as improper. Even the merchant will ſcarce find reaſon to repent his having been introduced to the acquaintance of Plato and Cicero. But ſtill, if the circumſtances of the parent, or any other juſt reaſon, ſhould render it inconvenient, to ſend the young man who is intended for trade to a free ſchool to ſtudy the ancient languages, means may be eaſily adopted to make up for his loſs. Confine him not to writing and accounts alone. Theſe, though particularly uſeful to the merchant, have no great power to reſtrain the force of evil paſſions, or to inſpire the mind with generous and virtuous ſentiments. Though you burden him not with Latin and Greek, yet ſtrive to inſpire him with a taſte for uſeful knowledge and for elegant literature. Some of the pureſt and moſt elegant of our poets, the excellent periodical works which have appeared in our language, ſuch as the Spectator, the Adventurer, the Mirror, and the compoſitions of our Britiſh hiſtorians, together with ſome of the beſt tranſlations of the claſſics which we poſſeſs; theſe you may with great propriety put into his hands. They will teach him how to think and reaſon juſtly, and to expreſs himſelf in converſation or in writing with correctneſs and elegance: they will refine and poliſh his mind, and raiſe him above low and groſs pleaſures. And as no man, who has any occaſion to ſpeak or write, ought to be entirely ignorant of the principles of grammar, you will therefore be careful to inſtruct the young man who is deſigned for a mercantile occupation in the grammar of his mother tongue.

75 Integrity.

A ſacred regard to his engagements, and an honeſty which may prevent him from taking undue advantages or exacting unreaſonable profits, are the virtues which a merchant is moſt frequently called to exerciſe: punctuality and integrity are the duties moſt particularly incumbent on the mercantile profeſſion. Temptations will now and then ariſe to ſeduce the merchant to the violation of theſe. But if ſuperior to every ſuch temptation, he is one of the moſt illuſtrious characters, and is likely to be one of the moſt ſucceſsful merchants. From his earlieſt years, then, labour to inſpire the child whom you intend for trade with a ſacred regard for truth and juſtice: let him be taught to view deceit and fraud, and the violation of a promiſe, with abhorrence and diſdain. Frugality is a virtue which, in the preſent age, ſeems to be antiquated or proſcribed. Even the merchant often appears better ſkilled in the arts of profuſion than in thoſe of parſimony. The miſer, a character at no time viewed as amiable, is at preſent beheld with double deteſtation and contempt. Yet, notwithſtanding theſe unfavourable circumſtances, fear not to impreſs upon the young merchant habits of frugality. Let him know the folly of beginning to ſpend a fortune before he have acquired it. Let him be taught to regard a regular attention to confine his expences within due bounds, as one of the firſt virtues which can adorn his character.

76 Induſtry.

Frugality and induſtry are ſo cloſely connected, that when we recommend the one of them to the merchant, we will be naturally underſtood to recommend the other alſo. It is eaſy to ſee, that without induſtrious application, no man can reaſonably expect to meet with ſucceſs in the occupation in which he engages; and if the merchant thinks proper to leave his buſineſs to the management of clerks and ſhop-keepers, it is not very probable that he will quickly accumulate a fortune. It is, therefore, no leſs neceſſary, that he who is intended for trade be early accuſtomed to habits of ſober application, and be carefully reſtrained from volatility and levity, than that he be inſtructed in writing, arithmetic, and keeping of accounts.

With theſe virtues and qualifications the merchant is likely to be reſpectable, and not unſucceſsful, while he continues to proſecute his trade: and if, by the bleſſing of Providence, he be at length enabled to accumulate a moderate fortune, his acquaintance with elegant literature, and the various habits which he has acquired, will enable him to enjoy it with taſte and dignity. Indeed, all the advantages which a man without taſte, or knowledge, or virtue, can derive from the poſſeſſion of even the moſt ſplendid fortune, are ſo inconſiderable, that they can be no adequate reward for the toil which he undergoes, and the mean arts which he practiſes in acquiring it. At the head of a great fortune a fool can only make himſelf more ridiculous, and a man of a wicked and vicious character more generally abhorred, than if fortune had kindly concealed their crimes and follies by placing them in a more obſcure ſtation.

77
Education of perſons in the loweſt ranks.

A conſiderable part of the members of ſociety are placed in ſuch circumſtances, that it is impoſſible for them to receive the advantages of a liberal education. The mechanic and the huſbandman, who earn a ſubſiſtence by their daily labour, can ſeldom afford, whatever parental fondneſs may ſuggeſt, to favour their children with many opportunities of literary inſtruction. Content if they can provide them with food and raiment till ſuch time as they acquire ſufficient ſtrength to labour for their own ſupport, parents in thoſe humble circumſtances ſeldom think it neceſſary that they ſhould concern themſelves about giving their children learning. Happily it is not requiſite that thoſe who are deſtined to ſpend their days in this low ſphere ſhould be furniſhed with much literary or ſcientific knowledge. They may be taught to read their mother tongue, to write, and to perform ſome of the moſt common and the moſt generally uſeful operations of arithmetic: for without an acquaintance with the art of reading, it will ſcarce be poſſible for them to acquire any rational knowledge of the doctrines and precepts of religion, or of the duties of morality; the invaluable volume of the ſacred Scriptures would be ſealed to them: we may allow them to write, in order that they may be enabled to enjoy the ſweet ſatisfaction of communicating accounts of their welfare to their abſent friends; and, beſides, both writing and arithmetic are neceſſary for the accompliſhment of thoſe little tranſactions which paſs among them. It would be hard, if even the loweſt and pooreſt were denied theſe ſimple and eaſily acquired branches of education; and happily that degree of ſkill in them which is neceſſary for the labourer and the mechanic may be attained without greater expence than may be afforded by parents in the meaneſt circumſtances. Let the youth who is born to paſs his days in this humble ſtation be carefully taught to conſider honeſt patient induſtry as one of the firſt of virtues: let him be taught to regard the ſluggard as one of the moſt contemptible of characters: teach him contentment with his lot, by letting him know that wealth and honour ſeldom confer ſuperior happineſs: Yet ſcruple not to inform him, that if he can raiſe himſelf above the humble condition to which he was born, by honeſt arts, by abilities virtuouſly exerted, he may find ſome comfort in affluent circumſtances, and may find reaſon to rejoice that he has been virtuous, induſtrious, and active. In teaching him the principles of religion, be careful to ſhow him religion as intimately connected with morality: teach him none of thoſe myſterious doctrines, whoſe ſole tendency is to foſter that enthuſiaſm which naturally prevails among the vulgar, and to perſuade them that they may be pious without being virtuous. Labour to inſpire him with an invincible abhorrence for lying, fraud, and theft. Inſpire him with a high eſteem for chaſtity, and with an awful regard to the duties of a ſon, a huſband, and a father. Thus may he become reſpectable and happy, even in his humble ſtation and indigent circumſtances; a character infinitely ſuperior, in the eyes of both God and man, to the rich and great man who miſemploys his wealth and leiſure in ſhameful and vicious purſuits.

VIII. *On the Education of the Female Sex.*

THE abſtracts which we have given of ſome of the moſt celebrated and original treatiſes on education, as well as our own obſervations on this ſubject, have been hitherto either relative to the education of both the ſexes, or directed chiefly to the education of the male ſex. But as there is a natural difference between the characters of the two ſexes, and as there are certain duties peculiar to each of them; it is eaſy to ſee that the education of the boy and that of the girl cannot, ought not, to be conducted preciſely in the ſame manner. And ſince the duties of the female ſex are ſo important to ſociety, and they form ſo conſiderable a part of our ſpecies, their education, therefore, merits the higheſt attention.

78
Similarity of the characters of both ſexes in the firſt period of life.

In infancy, the inſtincts, the diſpoſitions, and the faculties of boys and girls ſeem to be nearly the ſame. They diſcover the ſame curioſity, and the ſame diſpoſition to activity. For a while they are fond of the ſame ſports and amuſements. But by and by, when we begin to make a diſtinction in their dreſs; when the girl begins to be more confined to a ſedentary life under her mother's eye, while the boys are permitted to ramble about without doors; the diſtinction between their characters begins to be formed, and their taſte and manners begin to become different. The boy now imitates the arts and the active amuſements of his father; digs and plants a little garden, builds a houſe in miniature, ſhoots his bow, or draws his little cart; while the girl, with no leſs emulation, imitates her mother, knits, ſews, and dreſſes her doll. They are no longer merely children; the one is now a girl, the other a boy. This taſte for female arts, which the girl ſo eaſily and naturally acquires, has been judiciouſly taken notice of by Rouſſeau, as affording a happy opportunity for inſtructing her in a very conſiderable part of thoſe arts which it is proper to teach her. While the girl is buſied in adorning her doll, ſhe inſenſibly becomes expert at needle work, and learns how to adjuſt her own dreſs in a becoming manner. And therefore, if ſhe be kindly treated, it will not be a matter of difficulty to prevail with her to apply to theſe branches of female education. Her mother or governeſs, if capable of managing her with mildneſs and prudence, may teach her to read with great facility. For being already more diſpoſed to ſedentary application than the boy of the ſame age, the confinement to which ſhe muſt ſubmit in order to learn to read will be leſs irkſome to her. Some have pretended that the reaſoning powers of girls begin to exert themſelves ſooner than thoſe of boys. But, as we have already declared our opinion, that the reaſoning powers of children of both ſexes begin to diſplay themſelves at a very early period; ſo we do not believe that thoſe of the one ſex begin to appear or attain maturity, ſooner than thoſe of the other. But the different occupations and amuſements in which we cauſe them to engage from their earlieſt years, naturally call forth their powers in different manners, and perhaps cauſe the one to imitate our modes of ſpeaking and behaviour ſooner than the other. However, as we wiſh both boys and girls to learn the art of reading at a very early age, even as ſoon as they are capable of any ſerious application ; ſo we wiſh girls to be taught the art of writing, arithmetic, and the principles of religion and morals, in the ſame order in which theſe are inculcated on boys.

We need not point out the reaſons which induce us to regard theſe as accompliſhments proper for the female ſex : they ſeem to be generally conſidered as not only ſuitable, but neceſſary. It is our moſt important privilege, as beings placed in a ſituation different from that of the inferior animals, that we are capable of religious ſentiments and religious knowledge ; it therefore becomes us to communicate religious inſtruction with no leſs aſſiduity and care to the youth of the female ſex than to thoſe of our own. Beſides, as the care of children during their earlier years belongs in a particular manner to the mother ; ſhe, therefore, whom nature has deſtined to the important duties of a mother, ought to be carefully prepared for the proper diſcharge of thoſe duties, by being accurately inſtructed, in her youth, in ſuch things as it will be afterwards requiſite for her to teach her children.

Ladies have ſometimes diſtinguiſhed themſelves as prodigies of learning. Many of the moſt eminent geniuſes of the French nation have been of the female ſex. 79 Erudition, how far becoming in ladies. Several of our countrywomen have alſo made a reſpectable figure in the republic of letters. Yet we cannot approve of giving girls a learned education. To acquire the accompliſhments which are more proper for their ſex, will afford ſufficient employment for their earlier years. If they be inſtructed in the grammar of their mother tongue, and taught to read and ſpeak it with propriety ; be taught to write a fair hand, and to perform with readineſs the moſt uſeful operations of arithmetic : if they be inſtructed in the nature of the duties which they owe to God, to themſelves, and to ſociety ; this will be almoſt all the literary inſtruction neceſſary for them. Yet we do not mean to forbid them an acquaintance with the literature of their country. The periodical writers, who have taught all the duties of morality, the decencies of life, and the principles of taſte, in ſo elegant and pleaſing a manner, may with great propriety be put into the hands of our female pupil. Neither will we deny her the hiſtorians, the moſt popular voyages and travels, and ſuch of our Britiſh poets as may be put into her hands without corrupting her heart or inflaming her paſſions. But could our opinion or advice have ſo much influence, we would endeavour to perſuade our countrymen and countrywomen to baniſh from among them the noveliſts, thoſe panders of vice, with no leſs determined ſeverity than that with which Plato excludes the poets from his republic, or that with which the converts to Chriſtianity, mentioned in the Acts, condemned their magical volumes to the flames. Unhappily, novels and plays are almoſt the only ſpecies of reading in which the young people of the preſent age take delight ; and nothing has contributed more effectually to bring on that diſſoluteneſs of manners which prevails among all ranks.

But we will not diſcover ſo much auſterity as to expreſs a wiſh that the education of the female ſex ſhould be confined ſolely to ſuch things as are plain and uſeful. 80 Ornamental accompliſhments. We forbid not thoſe accompliſhments which are merely ornamental, and the deſign of which is to render them amiable in the eyes of the other ſex. When we conſider the duties for which they are deſtined by nature, we find that the art of pleaſing conſtitutes no inconſiderable part of theſe ; and it would be wrong, therefore, to deny them thoſe arts, the end of which is to enable them to pleaſe. Let them endeavour to acquire taſte in dreſs : to dreſs in a neat graceful manner, to ſuit colours to her complexion, and the figure of her clothes to her ſhape, is no ſmall accompliſhment for a young woman. She who is rigged out by the taſte and dexterity of her maid and her milliner, is nothing better than a doll ſent abroad to public places as a ſample of their handywork. 81 Dancing. Dancing is a favourite exerciſe : nay, we might almoſt call it the favourite ſtudy of the fair ſex : So many pleaſing images are aſſociated with the idea of dancing ; dreſs, attendance, balls, elegance and grace of motion irreſiſtible, admiration, and courtſhip : and theſe are ſo early inculcated on the young by mothers and maids, that we need not be ſurpriſed if little Miſs conſider her leſſon of dancing as a matter of much more importance than either her book or ſampler. And indeed, though the public in general ſeem at preſent to place too high a value on dancing ; and though the undue eſtimation which is paid to it ſeems owing to that taſte for diſſipation, and that rage for public amuſements, which naturally prevail amid ſuch refinement and opulence ; yet ſtill dancing is an accompliſhment which both ſexes may cultivate with conſiderable advantage. It has a happy effect on the figure, the air, and the carriage ; and we know not if it be not favourable even to dignity of mind : Yet as to be even a firſt-rate poet or painter, and to value himſelf on his genius in theſe arts, would be no real ornament in the character of a great monarch ; ſo any very ſuperior ſkill in dancing muſt ſerve rather to diſgrace than to adorn the lady or the gentleman. There are ſome arts in which, though a moderate degree of ſkill may be uſeful or ornamental, yet ſuperior taſte and knowledge are rather hurtful, as they have a tendency to ſeduce us from the more important duties which we owe to ourſelves and to ſociety. Of thoſe, dancing ſeems to be one : It is ſaid of a certain Roman lady, by an eloquent hiſtorian, " that ſhe was more ſkilled in dancing than became a modeſt and virtuous woman."

82 Muſic. Muſic, alſo, is an art in which the youth of the female ſex are pretty generally inſtructed ; and if their voice and ear be ſuch as to enable them to attain any excellence in vocal muſic, it may conduce greatly to increaſe their influence over our ſex, and may afford a pleaſing and elegant amuſement to their leiſure hours. The harpſichord and the ſpinet are inſtruments often touched by female hands ; nor do we preſume to forbid the ladies to exerciſe their delicate fingers in calling forth the enchanting ſounds of theſe inſtruments. But ſtill, if your daughter have no voice or ear for muſic, compel her not to apply to it.

83 Drawing. Drawing is another accompliſhment which generally enters into the plan of female education. Girls are uſually taught to aim at ſome ſcratches with a pencil : but when they grow up, they either lay it totally aſide, or elſe apply to it with ſo much aſſiduity as to neglect their more important duties. We do not conſider ſkill in drawing, any more than ſkill in poetry, as an accompliſhment very neceſſary for the ladies ; yet we agree with Rouſſeau, that as far as it can contribute to improve their taſte in dreſs, it may not be improper for them

them to purſue it. They may very properly be taught to ſketch and colour flowers; but we do not wiſh them to forget or lay aſide this as ſoon as the drawing-maſter is diſmiſſed: let them retain it to be uſeful through life. Though pride can never be lovely, even in the faireſt female form; yet ought the young woman to be carefully impreſſed with a due reſpect for herſelf. This will join with her native modeſty to be the guardian of her virtue, and to preſerve her from levity and impropriety of conduct.

Such are the hints which have occurred to us on the education proper for the female ſex, as far as it ought to be conducted in a manner different from that of the male.

IX. *Public and Private Education.*

ONE queſtion uſually diſcuſſed by the writers on this ſubject has not hitherto engaged our attention. It is, Whether it be moſt proper to educate a young man privately, or ſend him to receive his education at a public ſchool? This queſtion has been ſo often agitated, and by people enjoying opportunities of receiving all the information which experience can furniſh on the ſubject, that we cannot be expected to advance any new argument of importance on either ſide. Yet we may ſtate what has been urged both on the one and the other.

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Arguments for private education.

They who have conſidered children as receiving their education in the houſe and under the eye of their parents, and as ſecluded in a great meaſure from the ſociety of other children, have been ſometimes led to conſider this ſituation as particularly favourable for their acquiring uſeful knowledge, and being formed to virtuous habits. Though we reap many advantages from mingling in ſocial life, yet in ſociety we are alſo tainted with many vices to which he who paſſes his life in ſolitary retirement is a ſtranger. At whatever period of life we begin to mix with the world, we ſtill find that we have not yet acquired ſufficient ſtrength to reſiſt thoſe temptations to vice with which we are there aſſailed. But if we are thus ready to be infected with the contagion of vice, even at any age, no other argument can be neceſſary to ſhow the propriety of confining children from thoſe dangerous ſcenes in which this infection is ſo eaſily caught. And whoever ſurveys the ſtate of morals in a public ſchool with careful and candid attention, even though it be under the management of the moſt virtuous, judicious, and aſſiduous teachers, will find reaſon to acknowledge, that the empire of vice is eſtabliſhed there not leſs fully than in the great world. Nothing, therefore, can be more negligent or inhuman, than for parents to expoſe their children to thoſe ſeductions which a great ſchool preſents, at a time when they are ſtrongly diſpoſed to imitate any example ſet before them, and have not yet learned to diſtinguiſh between ſuch examples as are worthy of imitation, and thoſe which ought to be beheld with abhorrence. Even when under the parent's eye, from intercourſe with ſervants and viſitors their native innocence is likely to ſuffer conſiderably. Yet the parent's care will be much more likely to preſerve the manners of his child uncorrupted in his own houſe, than any aſſiduity and watchfulneſs of his teachers in a ſchool.

The morals and diſpoſitions of a child ought to be the firſt objects of our concern in conducting his education: but to initiate him in the principles of uſeful knowledge is alſo an important object; and it will be happy, if in a private education virtue be not only better ſecured, but knowledge alſo more readily acquired, than in a public. But this actually happens. When one or two boys are committed to the care of a judicious tutor, he can watch the moſt favourable ſeaſons for communicating inſtruction; he can awake curioſity and command attention by the gentle arts of inſinuation: though he ſtrive not to inflame their breaſts with emulation, which leads often to envy and inveterate hatred; yet he will ſucceed in rendering learning pleaſing, by other means leſs likely to produce unfavourable effects on the temper and diſpoſitions of his pupils. As his attention is not divided among a number, he can pay more regard to the particular diſpoſitions and turn of mind of each of his pupils: he can encourage him who is modeſt and ſlow, and repreſs the quickneſs and volatility of the other; and he can call forth and improve their powers, by leading them at one time to view the ſcenes of nature and the changes which ſhe ſucceſſively undergoes through the varying ſeaſons: at another, to attend to ſome of the moſt entertaining experiments of natural philoſophy; and again alluring them artfully to their literary exerciſes. With theſe he may mix ſome active games; and he may aſſume ſo much of the fondneſs of the parent, as to join in them with his little pupils. Theſe are certainly circumſtances favourable both to the happineſs and to the literary improvement of youth; but they are peculiar to a private education. Beſides, in a private education, as children ſpend more of their time with grown-up people than in public; thoſe, therefore, who receive a domeſtic education, ſooner acquire our manner of thinking, of expreſſing ourſelves, and of behaving in our ordinary intercourſe with one another. For the very ſame reaſon for which girls are often obſerved to be capable of prudence and propriety of behaviour at an earlier age than boys, thoſe boys who receive a family education will begin ſooner to think and act like men, than thoſe who paſs their earlier days in a public ſeminary. And though you educate your ſon at home, there is no reaſon why he ſhould be more accuſtomed to domineer over his inferiors, or to indulge a capricious or inhumane diſpoſition, than if he were brought up among fifty boys, all of the ſame age, ſize, and rank, with himſelf. He may alſo, in a private education, exerciſe his limbs with the ſame activity as in a public one. He cannot indeed engage in thoſe ſports for which a party of companions is neceſſary; but ſtill there are a thouſand objects which will call forth his activity: if in the country, he will be diſpoſed to fiſh, to climb for bird neſts, to imitate all that he ſees performed by labourers and mechanics: in ſhort, he will run, leap, throw and carry ſtones, and keenly exert himſelf in a variety of exerciſes, which will produce the moſt favourable effects on the powers both of his mind and body. It may indeed be poſſible for you to oppoſe the deſigns of nature ſo effectually, if you take pains for that purpoſe, as to repreſs the natural activity of your child or pupil, and cauſe him to pine away his time in liſtleſs indolence; but you will thus do violence to his diſpoſitions, as well as to thoſe inſtincts which nature has for wiſe purpoſes implanted in his breaſt.

And

And the bad conſequences which may reſult from this management are not to be conſidered as the natural effects of a domeſtic education, but as the effects of an education careleſsly or imprudently conducted.

But there is another conſideration which will perhaps be ſtill more likely than any of thoſe which we have hitherto urged, to prevail with the fond parent to give his child a private education. As the infant who is abandoned by its mother to the care of an hireling nurſe, naturally transfers its affection from the unnatural parent to the perſon who ſupplies her room and performs the duties incumbent upon her; ſo the boy who is baniſhed from a parent's houſe at a time when he has ſcarce begun to know the relation in which he ſtands to his father and mother, brothers or ſiſters, ſoon ceaſes to regard them with that fondneſs which he had contracted for them from living in their company and receiving their good offices. His reſpect, his affection, and his kindneſs, are beſtowed on new objects, perhaps on his maſter or his companions; or elſe his heart becomes ſelfiſh and deſtitute of every tender and generous feeling; and when the gentle and amiable affections of filial and fraternal love are thus, as it were, torn up by the roots, every evil paſſion ſprings up, with a rapid growth, to ſupply their place. The boy returns afterwards to his father's houſe: but he returns as a ſtranger; he is no longer capable of regarding his parents and relations with the ſame tenderneſs of affection. He is now a ſtranger to that filial love which ſprings up in the breaſt of the child who is conſtantly ſenſible of the tender care of his parents, and ſpends his earlier years under their roof, in ſuch a manner as to appear the effect of inſtinct rather than of habit. Selfiſh views are now the only bond which attaches him to his parents and relations; and by coming under their influence at ſo early a period of life, he is rendered for ever incapable of all the moſt amiable virtues which can adorn human nature. Let the parent, therefore, who loves his child, and wiſhes to obtain from him a mutual return of affection, beware of excluding him from his houſe, and devolving the ſole charge of him upon another, in his childhood.

Theſe views repreſent a private education as the moſt favourable to virtue, to knowledge, and to the mutual affection which ought always to unite the parent and his child. But let us now liſten to the arguments which are uſually urged in behalf of a public education.

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Arguments for public education.

In the firſt place, it has been aſſerted, that a public education is much more favourable than a private to the pupil's improvement in knowledge, and much more likely to inſpire him with an ardour for learning. In a private education, with whatever aſſiduity and tenderneſs you labour to render learning agreeable to your pupil, ſtill it will be but an irkſome taſk. You may confine him to his books but for a very ſhort ſpace in the courſe of the day, and allow him an alternation of ſtudy and recreation. Still, however, you will never be able to render his books the favourite objects of his attention. He will apply to them with reluctance and careleſs indifference; even while he ſeems engaged on his leſſon, his mind will be otherwiſe occupied; it will wander to the ſcenes where he purſues his diverſions, and to thoſe objects which have attracted his deſires. If the period during which you require his application be extremely ſhort; during the firſt part of it, he will ſtill be thinking of the amuſements from which you have called him, and regretting his confinement; during the laſt, he will fondly anticipate the moment when he is to be ſet at liberty, and think of new amuſements. Again, if you confine him during a longer period, ſtill more unfavourable effects will follow. Peeviſhneſs, dullneſs, and a determined averſion to all that bears the name of literature, will be naturally impreſſed on his mind by ſuch treatment. How can it be otherwiſe? Books poſſeſs ſo few of thoſe qualities which recommend any object to the attention of children, that they cannot be naturally agreeable. They have nothing to attract and detain the eye, the ear, or any of the ſenſes; they preſent things with which children are unacquainted, and of which they know not the value: children cannot look beyond the letters and words, to the things which theſe repreſent; and even though they could, yet it is much more pleaſing to view ſcenes and objects as they exiſt originally in nature, than to trace their images in a faint and imperfect repreſentation. It is vain, therefore, to hope that children will be prevailed with to pay attention to books by means of any allurements which books can of themſelves preſent. Other means muſt be uſed; but thoſe in a private education you cannot command. In a public ſeminary, the ſituation of maſters with reſpect to their pupils is widely different. When a number of boys meet together in the ſame ſchool, each of them ſoon begins to feel the impulſe of a principle which enables the maſter to command their attention without difficulty, and prompts them to apply with cheerful ardour to taſks which would otherwiſe be extremely irkſome. This principle is a generous emulation, which animates the breaſt with the deſire of ſuperior excellence, without inſpiring envy or hatred of a competitor. When children are prudently managed in a great ſchool, it is impoſſible for them not to feel its impulſe. It renders their taſks ſcarce leſs agreeable than their amuſements, and directs their activity and curioſity to proper objects. View the ſcholar at a public ſchool, compoſing his theme, or turning over his dictionary; how alert! how cheerful! how indefatigable! He applies with all the eagerneſs, and all the perſeverance, of a candidate for one of the moſt honourable places in the temple of fame. Again, behold and pity that poor youth who is confined to his chamber with no companion but his tutor; none whoſe ſuperiority can provoke his emulation, or whoſe inferiority might flatter him with thoughts of his own excellence, and thus move him to preſerve by induſtrious application the advantages which he has already gained. His book is before him; but how languid, how liſtleſs his poſture! how heavy and dull his eye! Nothing is expreſſed in his countenance but dejection or indignation. Examine him concerning his leſſon; he replies with confuſion and heſitation. After a few minutes obſervation, you cannot fail to be convinced that he has ſpent his time without making any progreſs in learning; that his ſpirits are now broken, his natural cheerfulneſs deſtroyed, and his breaſt armed with invincible prejudices againſt all application in the purſuit of literary knowledge. Beſides, in a ſchool there is ſomething more than emulation to render learning

ing leſs diſagreeable than it naturally is to children. The ſlighteſt obſervation of life, or attention to our own conduct in various circumſtances, will be ſufficient to convince us, that whenever mankind are placed in circumſtances of diſtreſs, or ſubjected to any diſagreeable reſtraint, that which a ſingle perſon bears with impatience or dejection will make a much leſs impreſſion on his mind if a number of companions be joined with him in his ſuffering or reſtraint. It is eſteemed a piece of much greater ſeverity to confine a priſoner in a ſolitary cell, than where he is permitted to mix with others in the ſame uncomfortable ſituation. A journey appears much leſs tedious to a party of travellers, than to him who beats the path alone. In the ſame manner, when a number of boys in a great ſchool are all buſied on the ſame or on ſimilar taſks, a ſpirit of induſtry and perſeverance is communicated from one to another over the whole circle; each of them inſenſibly acquires new ardour and vigour; even though he feel not the ſpur of emulation, yet, while all are buſy around him, he cannot remain idle. Theſe are facts obvious to the moſt careleſs obſerver.

Neither are public ſchools ſo unfavourable to the virtue of their members as they have been repreſented to be. If the maſters are men of virtue and prudence, careful to ſet a good example before their pupils, attentive to the particular character and behaviour of each individual among them, firm to puniſh obſtinate and incorrigible depravity, and even to expel thoſe who are more likely to injure the morals of others than to be reclaimed themſelves, and at the ſame time eager to applaud and to encourage amiable and virtuous diſpoſitions wherever they appear; under the government of ſuch maſters, a public ſchool will not fail to be a ſchool of virtue. There will no doubt be particular individuals among the pupils of ſuch a ſeminary, whoſe morals may be corrupt and their diſpoſitions vicious; but this, in all probability, will ariſe from the manner in which they were managed before entering the ſchool, or from ſome other circumſtances, rather than from their being ſent for their education to a public ſchool. Again, at a public ſchool young people enjoy much greater advantages for preparing them to enter the world, than they can poſſibly be favoured with if brought up in a private and ſolitary manner. A great ſchool is a miniature repreſentation of the world at large. The objects which engage the attention of boys at a ſchool are different from thoſe which occupy their parents; the views of the boys are leſs extenſive, and they are not yet capable of proſecuting them by ſo many baſe and mean arts: but, in other reſpects, the two ſcenes and the actors upon them nearly reſemble each other; on both you behold contending paſſions, oppoſite intereſts, weakneſs, cunning, folly, and vice. He therefore who has performed his part on the miniature ſcene, has rehearſed as it were for the greater; if he has acquitted himſelf well on the one, he may be alſo expected to diſtinguiſh himſelf on the other; and even he who has not diſtinguiſhed himſelf at ſchool, at leaſt enters the world with ſuperior advantages when viewed in compariſon with him who has ſpent his earlier days in the ignorance and ſolitude of a private and domeſtic education. Beſides, when a number of boys meet at a public ſeminary of education, ſeparated from their parents and relations; nearly of the ſame age, engaged in the ſame ſtudies, and fond of the ſame amuſements; they naturally contract friendſhips with one another which are more cordial and ſincere than any that take place between perſons farther advanced in life. A friendſhip is often formed between two boys at ſchool which continues through life, and is productive of the happieſt conſequences to each of them. While at ſchool, they mutually aſſiſt and encourage each other in their learning; and their mutual affection renders their taſks leſs burdenſome than they might otherwiſe find them. As they advance in life, their friendſhip ſtill continues to produce happy effects on their ſentiments and conduct: perhaps they are mutually uſeful to each other by intereſt or by perſonal aſſiſtance in making their way in the world; or when they are engaged in the cares and buſtle of life, their intercourſe and correſpondence with each other may contribute much to conſole them amid the vexations and fatigues to which they may be expoſed.

Such are the chief arguments uſually adduced in favour of a public education. When we compare them with thoſe which have been urged to recommend a private education, we ſhall perhaps find that each has its peculiar advantages. A public education is the more favourable to the acquiſition of knowledge, to vigour of mind, and to the formation of habits of induſtry and fortitude. A private education, when judiciouſly conducted, will not fail to be peculiarly favourable to innocence and to mildneſs of diſpoſition; and notwithſtanding what has ſometimes been advanced by the advocates for a public education, it is ſurely better to keep youth at a diſtance from the ſeductions of vice till they be ſufficiently armed againſt them, than to expoſe them to them at an age when they know not to what dangers they lead, and are wholly unable to reſiſt them. Were we to give implicit credit to the ſpecious talk of the two parties, either a private or a public education would form characters more like to angels than to thoſe men whom we ordinarily meet in the world: but they ſpeak with the ardour of enthuſiaſts; and therefore we muſt liſten with caution both to the facts which they adduce, and to the inferences which they draw. Could we without expoſing children to the contagion of a great town, procure for them the advantages of both a public and a private education at the ſame time, we would by this means probably ſucceed beſt in rendering them both reſpectable ſcholars and good men. If we may preſume to give our opinion freely, we would adviſe parents never, except when ſome unavoidable neceſſity of circumſtances obliges them, to expel their children from under their own roof till they be advanced beyond their boyiſh years: let the mother nurſe her own child; let her and the father join in ſuperintending its education: they may then expect to be rewarded, if they have acted their parts aright, by commanding the gratitude, the affection, and the reſpect of their child, while he and they continue to live together. Let matters be ſo ordered, that the boy may reſide in his father's houſe, and at the ſame time attend a public ſchool: but let the girl be educated wholly under her mother's eye.

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A medium between the two.

X. On

X. *On Travel.*

87 Travel conſidered in general.

Another queſtion which has been often diſcuſſed comes here under our review. The philoſophers of ancient Greece travelled in ſearch of knowledge. Books were then ſcarce, and thoſe few which were to be obtained were no very rich treaſuries of uſeful information. The rhapſodies of a poet, the rude legends of ſome ill-informed and fabulous hiſtorian, or the theories of fanciful philoſophers, were all that they could afford. Thales, Lycurgus, Solon, Plato, travelled, ſeeking that knowledge among more civilized nations which they could not find in their native country. In the courſe of their travels, they heard the lectures of celebrated philoſophers; conſulted the prieſts, who were the guardians of the traditions of antiquity, concerning the nature and origin of thoſe traditions; and obſerved the inſtitutions of thoſe nations which were moſt renowned for the wiſdom of their legiſlature. When they ſet out to viſit foreign countries, they ſeem to have propoſed to themſelves a certain end; and by keeping that end ſteadily in view during the courſe of their travels, they gained ſuch improvement as to be able on their return to command the veneration of their countrymen by means of the knowledge which they were enabled to communicate. Many beſides the philoſophers of ancient Greece have travelled for improvement, and have ſucceeded in their views. But ancient hiſtory does not relate to us, that travelling was conſidered by the Greeks or Romans as neceſſary to finiſh the education of their young men of fortune before they entered the ſcenes of active life. It is true, after Greece became a province of the Roman empire, and the Romans began to admire the ſcience and elegance of Greece, and to cultivate Grecian literature, the young noblemen of Rome often repaired to Rhodes and Athens to complete their ſtudies under the maſters of philoſophy and eloquence who taught in thoſe cities. But they went thither with the ſame views with which our youth in modern times are ſent to free ſchools and univerſities, not to acquire knowledge by the obſervation of nature, of the inſtitutions, manners, and cuſtoms of nations; but merely to hear lectures, read books, and perform exerciſes. In modern times, a few men of reflection and experience have now and then travelled for improvement: but the greateſt part of our travellers, for a long time, were enthuſiatic devotees who went in pilgrimage to viſit the ſhrine or relics of ſome favourite ſaint; ſoldiers, who wandered over the earth to deſtroy its inhabitants; or merchants, whoſe buſineſs as factors between widely diſtant countries and nations led them to brave every danger in traverſing from one corner of the globe to another. But ſince the nations of modern Europe have begun to emerge from rudeneſs, ignorance, and ſervile depreſſion, they have formed one great commonwealth, the members of which are ſcarce leſs intimately connected with each other than were the ſtates of ancient Greece. The conſequence of this mutual connexion and dependence is, that almoſt all the nations of Europe have frequent intercourſe with one another; and as ſome of them are, and have long been, more enlightened and refined than others, thoſe nations who have attained the higheſt degrees of civilization and refinement have naturally attracted the admiration and homage of the reſt. Their language has been ſtudied, their manners and arts have been adopted, and even their dreſs has been imitated. Other nations have thronged to pay the homage due to their ſuperior merit, and to ſtudy under them as maſters. Hence has ariſen the practice which at preſent prevails among us of ſending our youth to complete their education by travelling, before we introduce them to active life, or require them to engage in buſineſs. Formerly young men were not ſent to travel till after they had proceeded through the forms of a regular education, and had at leaſt attained ſuch an age that they were no longer to be conſidered as mere boys. But the progreſs of luxury, the deſire of parents to introduce their children into the world at an early age, that they may early attain to wealth and honours, and various other cauſes, have gradually introduced the practice of ſending mere boys to foreign countries, under pretence of affording them opportunities of ſhaking off prejudices, of ſtoring their minds with truly uſeful knowledge, and of acquiring thoſe graceful manners and that manly addreſs which will enable them to acquit themſelves in a becoming manner when they are called to the duties of active life. How much travelling at ſuch an early age contributes to fulfil the views of parents, a ſlight ſurvey of the ſenate-houſe, the gambling-houſes, the race-courſe, and the cockpit, will readily convince the ſagacious obſerver.

But we wiſh to foſter no prejudices againſt neighbouring nations; we entertain no ſuch prejudices in favour of Britain, as to wiſh to confine our countrymen within the ſea-girt iſle. Let us inquire what advantages may be gained by travelling, and at what age it may be moſt proper to ſet out in purſuit of thoſe advantages.

88 Travel neceſſary to the acquiſition of knowledge.

After all that bookiſh men have urged, and notwithſtanding all that they may continue vehemently to urge, in behalf of the knowledge to be derived from their beloved books; it muſt ſtill be acknowledged, that books can teach us little more than merely the language of men. Or, if we ſhould grant that books are of higher importance, and that language is the leaſt valuable part of the knowledge which they teach, yet ſtill we need to beware that they lead us not aſtray; it is better to examine nature with the naked eye, than to view her through the ſpectacles of books. Neither the theories or experiments of philoſophers, nor the narratives of travellers, nor the relations of hiſtorians, though ſupported by a numerous train of authorities, are worthy of implicit credit. You retire from the world, confine yourſelf for years to your cloſet, and read volume after volume, hiſtorians, philoſophers, and poets; at laſt you fancy that you have gained an immenſe ſtore of knowledge: But leave your retirement, return into the world, compare the knowledge which you have treaſured up with the appearances of nature; you will find that you have laboured in vain, that it is only the ſemblance of knowledge which you have acquired, and will not ſerve for a faithful guide in life, nor even enable you to diſtinguiſh yourſelf for literary merit. Compare the relations of travellers with one another; how ſeldom do they agree when they deſcribe the ſame ſcenes and the ſame people! Turn your attention to the moſt reſpectable hiſtorians, compare their accounts of the ſame events; what diſagreement! what contrariety! Where ſhall truth be found? Liſten to the cool, the candid philoſophers; what contradictory theories do they build on the ſame ſyſtem of facts!

We agree, then, that it is better to ſeek knowledge by actual obſervation and experiment, than to receive it at ſecond hand from the information of others. He who would gain an acquaintance with the beauties of external nature, muſt view them with his own eyes; he who would know the operations of the human underſtanding, muſt reflect upon what paſſes in his own mind; he who would know the cuſtoms, opinions, and manners of any people, muſt mingle with them, muſt obſerve their conduct, and liſten to their converſation. The arts are acquired by actual practice; the ſciences by actual obſervation in your own perſon, and by deducing inferences from your obſervations.

If therefore to extend our knowledge can contribute in any degree to render us happier, wiſer, or better; travelling, as being more favourable to knowledge than the ſtudy of books, muſt be highly advantageous. Get well acquainted with your own country; with the manners, the cuſtoms, the laws, and the political ſituation of your countrymen: Get alſo a knowledge of books; for books would not be altogether uſeleſs, though they could ſerve no other purpoſe but to teach us the language in which mankind expreſs themſelves: And then, if your judgment have attained maturity; if curioſity prompt you; if your conſtitution be robuſt and vigorous, and your ſpirits lively; you may imitate the Solons, Homers, and Platoes, of old, and viſit foreign countries in ſearch of knowledge, and with a view to bring home ſomething which may be of real utility to yourſelf and your country. You will, by this time, be ſo much maſter of the language of your own country, that you will not loſe it while you are learning the languages of foreign nations; your principles of taſte and of right and wrong will be ſo formed and fixed, that you will not deſpiſe any inſtitution or cuſtom or opinion merely becauſe it prevails not in your own country; nor yet will you be ready to admire and adopt any thing, merely becauſe it prevails among a foreign nation who are diſtinguiſhed for profound and extenſive knowledge, or for elegance of taſte and manners. No; you will diveſt yourſelf of every prejudice, and judge only by the fixed unalterable principles which determine the diſtinction between right and wrong, between truth and falſehood, between beauty and deformity, ſublimity and meanneſs. Your object will not be to learn exotic vices, to mingle in frivolous amuſements, or to form a catalogue of inns. Your views, your inquiries, will have a very different direction. You will attend to the ſtate of the arts, of the ſciences, of morals, manners, and government; you will alſo contemplate with eager delight, the grand or beautiful ſcenes of nature, and examine the vegetable productions of the various regions through which you paſs, as well as the different tribes of animals which inhabit them; you will obſerve what bleſſings the beneficence of nature has conferred on the inhabitants of each particular diviſion of the globe, and how far the ingenuity and induſtry of man have taken advantage of the kindneſs of nature. Thus ſurveying the face of the earth, and conſidering how advantages and diſadvantages are balanced with each other through every various region and climate from one extremity of the globe to another; you will admire and revere that impartiality with which the Author of nature has diſtributed his benefits to the whole human race. When from the chilly climes and ſtubborn ſoil of the north, you turn your eyes to the fertile genial regions of the ſouth, where every tree is loaded with exquiſite fruits, and every vegetable is nouriſhing and delicious; you will be pleaſed to find, that the inhabitants of the north, by their ſuperior ingenuity and vigour, are able to raiſe themſelves to circumſtances no leſs comfortable and reſpectable than thoſe which the nations inhabiting between the tropics enjoy: when you behold the French ſhaking off the yoke of deſpotiſm, and aſpiring to the ſweets of liberty as well as their Britiſh neighbours; you will be pleaſed to ſee, that the natural gaiety and cheerfulneſs of the former nation render them not incapable of the energy of the latter. You will be pleaſed to view the remains of antiquity, and the noble monuments of art; but you will think it below you to trifle away your time in gazing at palaces and churches, and collecting ruſty medals and fragments of marble; you will ſeek the ſociety of eminent men, and eagerly cultivate an acquaintance with the moſt diſtinguiſhed artiſts and men of ſcience who adorn the nations among whom you may happen to ſojourn. Knowing that the knowledge which is to be acquired in great towns, is by no means an adequate compenſation for the vicious habits which you are liable to contract in them; and beſides, that the luxuries, the arts, the manners, the virtues, and the vices of all great towns are nearly the ſame, ſo that when you have ſeen one, you have ſeen all others; you will avoid taking up your reſidence for any conſiderable time in any of the great towns through which you have occaſion to paſs in the courſe of your travels. The traveller who has attained the previous accompliſhments which we have mentioned as neceſſary, who ſets out with the views which we have ſuppoſed him to entertain, and who conducts his travels in this manner, cannot fail to return home enriched with much uſeful knowledge; he cannot but derive more real improvement from travelling, than he could have gained by ſpending the ſame period of time in ſolitary ſtudy: when he returns to his native country, he will appear among his countrymen as more than a philoſopher; a ſage, and a benefactor. His knowledge is ſo extenſive and accurate, his views are ſo liberal and enlarged, and he is ſo ſuperior to prejudices, without being the enemy of any uſeful eſtabliſhments, that he will be enabled to command univerſal eſteem, by performing his part in life with becoming dignity and propriety, and perhaps to render his name illuſtrious, and his memory dear to future times, by ſome important ſervices to the community to which he belongs, or even to mankind in general.

59
Circumſtances that render travelling unprofitable to the youth of the preſent age.

But though we have thus far, and we hope for obvious and ſolid reaſons, decided in favour of travelling, as being more likely than a ſolitary application to books, to furniſh the mind with uſeful and ornamental knowledge; yet we do not ſee that our Britiſh youth either take care to furniſh themſelves with the previous knowledge which we conſider as indiſpenſably neceſſary in order to prepare them for travelling with advantage, or ſet out with proper views, or proſecute

ſecute their travels in a prudent judicious manner. After receiving a very imperfect education, in which religious and moral inſtruction are almoſt wholly neglected, and no means are uſed to inſpire the youthful mind with ſolid, virtuous, manly qualities; but every art is tried to make the young man appear learned, while his mind is deſtitute of all uſeful information, and to teach him to aſſume the confidence of manhood before he has attained even to a moderate degree of ſenſe and prudence;—after an education conducted in this manner, and with theſe views, the ſtripling is ſent abroad to view the world, and is expected to return home a finiſhed character, an ornament and a comfort to his parents and all his connexions. He is hitherto unacquainted, perhaps, even with the ſimple events of the hiſtory of his native country; and either totally ignorant of claſſical literature, or but very ſuperficially inſtructed in it. He has not yet viewed with a diſcerning eye the manners and cuſtoms prevailing among his countrymen; he knows not the nature of the government under which he lives, nor the ſpirit of thoſe laws by which his civil conduct muſt be regulated. He has no fixed principles; no clear, diſtinct views. But to ſupply all his wants of this nature, he is put into the hands of a travelling governor, who is to be entirely ſubmiſſive to his will, and yet to ſerve him both for eyes and intellect. This governor is generally either ſome macaroni officer, who is conſidered as well bred, and thought to know the world; or elſe, perhaps, ſome cringing ſon of literature, who having ſpent much time among his books, without acquiring ſuch ſtrength or dignity of mind as to raiſe him above frivolity of manners and converſation or pitiful fawning arts, is therefore regarded as happily qualified for this important charge. This reſpectable perſonage and his pupil are ſhipped off for France, that land of elegant diſſipation, frivolity, and faſhion. They travel on with eager impatience, till they reach the capital. There the young man is induſtriouſly introduced to all the gay ſcenes which Paris can diſplay. He is, at firſt, confounded; by and by his ſenſes are faſcinated; new deſires are awaked in his breaſt; all around him he ſees the ſons of diſſipation wallowing in debauchery, or the children of vanity fluttering about like ſo many gawdy inſects. The poor youth has no fixed principles: he has not been taught to regard vanity as ridiculous, or to turn from vice with abhorrence. No attempt is made to allure him to thoſe objects, an attention to which can alone render travelling truly beneficial. Hitherto his mind had been left almoſt wholly uncultivated; and now the ſeeds of vice are plentifully ſown in it. From one great town he is conveyed to another, till he viſit almoſt every place in Europe where profligacy of manners has attained to any uncommon height. In this happy courſe of education he probably continues to purſue improvement till he is well acquainted with moſt of the poſt roads, the principal inns, and the great towns at leaſt in France and Italy; and perhaps till he has worn out his conſtitution, and rendered his mind totally incapable of any generous ſentiments or ſober reflection. He then reviſits his native country, to the inexpreſſible happineſs of his parents, who now eagerly long to embrace their all-accompliſhed child. But how miſerably are the poor folks diſappointed, when they find his conſtitution waſted, his underſtanding uninformed, his heart deſtitute of every manly or generous ſentiment: and perceive him to poſſeſs no accompliſhment, but ſuch as are merely ſuperficial? Perhaps, however, his parents are prevented by their partiality both for their child and for the means which they have adopted in conducting his education, from viewing his character and qualifications in a true light. Perhaps they overlook all his defects, or conſider them as ornaments, and regard their dear ſon as the mirror of perfection. But, unfortunately, though they be blind to the hideous deformity of the monſter which they have formed, they cannot hinder it from being conſpicuous to others; though they may view their ſon's character as amiable and reſpectable, they cannot render it uſeful, they cannot prevent it from being hurtful to ſociety. Let this youth whoſe education has been thus wiſely conducted, let him be placed at the head of an opulent fortune, advanced to a ſeat in the legiſlative body of his country, or called to act in any public character; how will he diſtinguiſh himſelf? As the virtuous patriot, the honeſt yet able ſtateſman, the ſkilful general, or the learned upright judge? How will he enjoy his fortune? Will he be the friend of the poor, the ſteady ſupporter of the laws and conſtitution under whoſe protection he lives? Will he ſhow himſelf capable of enjoying *otium cum dignitate?* If we reaſon by the uſual laws of probability, we cannot expect that he ſhould: and if we obſerve the manners and principles of our men of wealth and high birth who have been brought up in his manner, we find our reaſonings confirmed.

Such are the opinions which candid obſervation leads us to entertain with regard to the advantages which may be gained by travelling.

He whoſe mind has been judiciouſly cultivated, and who has attained to maturity of judgment, if he ſet out on his travels with a view to obtain real improvements, and perſiſt invariably in the proſecution of that view, cannot but derive very great advantages from travelling.

But again, thoſe young men whoſe minds have not been previouſly cultivated by a judicious education, who ſet out without a view to the acquiſition of real knowledge, and who wander among foreign nations, without attention to any thing but their luxuries, their follies, and their vices, thoſe poor young men cannot gain any real improvement from their travels.

Our countrymen, who travel for improvement, do not appear to derive ſo much advantage from their travels as were to be wiſhed, becauſe they generally receive too ſuperficial an education, ſet out at too early a period of life, and direct not their views to objects of real utility and importance.

XI. *On Knowledge of the World, and Entrance into Life.*

90
Unhappy effects of a too early introduction into the world.

Much has been ſaid concerning the utility of a knowledge of the world, and the advantage of acquiring it at an early period of life. But thoſe who have the moſt earneſtly recommended this knowledge of the world, have generally explained themſelves in ſo inaccurate a manner concerning it, that it is difficult to underſtand what ideas they affix to it. They ſeem to wiſh,

wiſh, that, in order to acquire it, young people may be early made acquainted with all the vices and follies of the world, introduced into polite company, carried to public places, and not confined even from the gaming table and the ſtews. Some knowledge of the world may, no doubt, be gained by theſe means. But it is ſurely dearly purchaſed; nor are the advantages which can be derived from it ſo conſiderable, as to tempt the judicious and affectionate parent to expoſe his child to the infection of vanity, folly, and vice, for their ſake. Carry a boy or girl into public life at the age of fourteen or fifteen; ſhow them all the ſcenes of ſplendid vanity and diſſipation which adorn London or Paris; tell them of the importance of dreſs, and of the ceremonies of good breeding and the forms of intercourſe; teach them that faſhionable indifference and aſſurance which give the *ton* to the manners of our fine gentlemen and fine ladies of the preſent age. What effects can you expect the ſcenes into which you introduce them, and the myſteries which you now teach them, to produce on the minds of the children? They have a direct tendency to inſpire them with a taſte for vanity, frivolity, and diſſipation. If you wiſh them to be like the fooliſh, the diſſipated, and the gay, you are likely to obtain your purpoſe; but if, on the contrary, your views are to prepare them for diſcharging the duties of life, you could not adopt more improper means: for though they be well acquainted with all thoſe things on which you place ſo much value, yet they have not thereby gained any acceſſion of uſeful knowledge. They are not now more able than before to eſtimate the real value of objects; nay, their judgement is now more liable than before to be miſled in eſtimating the value of the objects around them. Luxury, vanity, and faſhion, have ſtamped on many things an ideal value. By mingling at an early age in thoſe ſcenes of the world where luxury, vanity, and faſhion, reign with arbitrary ſway, young people are naturally impreſſed with all thoſe prejudices which theſe have a tendency to inſpire. Inſtead of acquiring an uſeful knowledge of the world, they are rendered incapable of ever viewing the world with an unprejudiced and diſcerning eye. If poſſible, therefore, we ſhould rather labour to confine young people from mingling in the ſcenes of gay and diſſipated life till after they have attained maturity of age and judgment. They will then view them in a proper light, and perhaps be happy enough to eſcape the infectious contagion of vice.

91
What knowledge of the world may be ſafely communicated to young people.

But there is another and a more valuable knowledge of the world, which we ought induſtriouſly to communicate to them as ſoon as they are capable of receiving it. As ſoon as they are made thoroughly acquainted with the diſtinctions between right and wrong, between virtue and vice, between piety and impiety, and have become capable of entering into our reaſonings; we ought then to inform them concerning the various eſtabliſhments and inſtitutions which exiſt in ſociety; concerning the cuſtoms, opinions, and manners of mankind; and concerning the various degrees of ſtrength or weakneſs of mind, of ingenuity or dullneſs, of virtuous or vicious qualities, which diſcriminate thoſe characters which appear in ſociety. We ought alſo to ſeize every opportunity which may be preſented of exemplifying our leſſons by inſtances in real life. We muſt point out to them thoſe circumſtances which have led mankind to place an undue value on ſome objects, while they appretiate others much below their real utility and importance. Thus let us fortify their judgements againſt that impreſſion which the dazzling novelty of the ſcene, and the force of paſſion, will be apt to produce; and communicate to them a knowledge of the world, without expoſing them imprudently to the contagion of its vices and follies.

When at length the period arrives at which they muſt be emancipated from ſubjection, and committed to the guidance of their own conſcience and reaſon, and of thoſe principles which we have laboured to inculcate on their minds; let us warn them of the dangers to which they are about to be expoſed; tell them of the glory and the happineſs to which they may attain; inſpire them, if poſſible, with diſdain for folly, vanity, and vice, whatever dazzling or enchanting forms they may aſſume; and then diſmiſs them to enrich their minds with new ſtores of knowledge by viſiting foreign nations; or, if that ſhould be inconvenient, to enter immediately on the duties of ſome uſeful employment in active life.

EDULCORATION, properly ſignifies the rendering ſubſtances more mild. Chemical edulcoration conſiſts almoſt always in taking away acids and other ſaline ſubſtances; and this is effected by waſhing the bodies to which they adhere in a large quantity of water. The waſhing of diaphoretic antimony, powder of algaroth, &c. till the water comes off quite pure and inſipid, are inſtances of chemical edulcoration.—In pharmacy, juleps, potions, and other medicines, are ſaid to be *edulcorated*, by adding ſugar or ſyrup.

EDWARD, the name of ſeveral kings of England. See (*Hiſtory of*) ENGLAND.

EDWARDS, GEORGE, fellow of the royal and antiquarian ſocieties, was born at Stratford, a hamlet belonging to Weſtham in Eſſex, on the 3d of April 1694. After having ſpent ſome time at ſchool, he was put apprentice to a tradeſman in Fenchurch ſtreet. His maſter, who was eminent both for his piety and ſkill in the languages, treated him with great kindneſs; but about the middle of his apprenticeſhip, an accident happened which totally put a ſtop to the hopes of young Edwards's advancing himſelf in the way of trade. Dr Nicolas, a perſon of eminence in the phyſical world, and a relation of his maſter's, happened to die. The Doctor's books were removed to an apartment occupied by Edwards, who eagerly employed all his leiſure hours, both in the day and great part of the night, in peruſing thoſe which treated of natural hiſtory, ſculpture, painting, aſtronomy, and antiquities. The reading of theſe books entirely deprived him of any inclination for mercantile buſineſs he might have formerly had, and he reſolved to travel into foreign countries. In 1716, he viſited moſt of the principal towns in Holland, and in about a month returned to England. Two years after, he took a voyage to Norway, at the invitation of a gentleman who was diſpoſed to be his friend, and who was nephew to the maſter of the ſhip in which he embarked. At this time Charles XII. was beſieging Frederickſhall; by which means our young naturaliſt was hindered from making ſuch excurſions into the country as otherwiſe he would have done, for the Swedes were very careful to confine ſuch ſtrangers as could not give a good account of themſelves. But notwithſtanding all his precaution, he was confined by the Daniſh guard, who ſuppoſed him to be a ſpy employed by the enemy to get intelligence of their deſigns. However, by obtaining teſtimonials of his innocence, a releaſe was granted. In 1718 he returned to England, and next year viſited Paris by the way of Dieppe. During his ſtay in this country he made two journeys of 100 miles each; the firſt to Chalons in Champagne, in May 1720; the ſecond on foot, to Orleans and Blois; but an edict happening at that time to be iſſued for ſecuring vagrants, in order to tranſport them to America, as the banks of the Miſſiſſippi wanted population; our author narrowly eſcaped a weſtern voyage. On his arrival in England, Mr Edwards cloſely purſued his favourite ſtudy of natural hiſtory, applying himſelf to drawing and colouring ſuch animals as fell under his notice. A ſtrict attention to natural, more than pictureſque beauty, claimed his earlieſt care: birds firſt engaged his particular attention; and having purchaſed ſome of the beſt pictures of theſe ſubjects, he was induced to make a few drawings of his own; which were admired by the curious, who encouraged our young naturaliſt to proceed, by paying a good price for his early labours. Among his firſt patrons and benefactors may be mentioned James Theobalds, Eſq. of Lambeth; a gentleman zealous for the promotion of ſcience. Our artiſt, thus unexpectedly encouraged, increaſed in ſkill and aſſiduity; and procured, by his application to his favourite purſuit, a decent ſubſiſtence and a large acquaintance. However, he remitted his induſtry in 1731; when, in company with two of his relations, he made an excurſion to Holland and Brabant, where he collected ſeveral ſcarce books and prints, and had an opportunity of examining the original pictures of ſeveral great maſters at Antwerp, Bruſſels, Utrecht, and other cities. In December 1733, by the recommendation of the great Sir Hans Sloane, Bart. preſident of the College of Phyſicians, he was choſen librarian, and had apartments in the college. This office was peculiarly agreeable to his taſte and inclination, as he had the opportunity of a conſtant recourſe to a valuable library, filled with ſcarce and curious books on the ſubject of natural hiſtory, which he ſo aſſiduouſly ſtudied. By degrees he became one of the moſt eminent ornithologiſts in this or any other country. His merit is ſo well known in this reſpect, as to render any eulogium on his performances unneceſſary: but it may be obſerved, that he never truſted to others what he could perform himſelf; and often found it ſo difficult to give ſatisfaction to his own mind, that he frequently made three or four drawings to delineate the object in its moſt lively character, attitude, and repreſentation. In 1743, the firſt volume of the Hiſtory of Birds was publiſhed in quarto. His ſubſcribers exceeding even his moſt ſanguine expectations, a ſecond volume appeared in 1747. The third volume was publiſhed in 1750. In 1751, the fourth volume came from the preſs. This volume being the laſt he intended to publiſh at that time, he ſeems to have conſidered it as the moſt perfect of his productions in natural hiſtory; and therefore devoutly offered it up to the great God of nature, in humble gratitude for all the good things he had received from him in this world. Our author, in 1758, continued his labours under a new title, viz. *Gleanings of Natural Hiſtory*. A ſecond volume of the Gleanings was publiſhed in 1760. The third part, which made the ſeventh and laſt volume of his works, appeared in 1764. Thus our author, after a long ſeries of years, the moſt ſtudious application, and the moſt extenſive correſpondence to every quarter of the world, concluded a work which contains engravings and deſcriptions of more than 600 ſubjects in natural hiſtory, not before deſcribed or delineated. He likewiſe added a general index in French and Engliſh; which was afterwards perfected, with the Linnæan names, by that great naturaliſt Linnæus himſelf, who frequently honoured him with his friendſhip and correſpondence. Some time after Mr Edwards had been appointed library keeper to the Royal College of Phyſicians, he was, on St Andrew's day, in the year 1750, preſented with an honorary compliment by the preſident and council of the Royal Society, with the gold medal, the donation of Sir Godfrey Copley, Bart. annually given on that day to the author of any new diſcovery in art or nature, in conſideration of his natural hiſtory juſt then completed. A copy of this medal he had afterwards engraved, and placed under the title in the firſt volume of his hiſtory. He was a few years afterwards elected fellow of the Royal Society, and of the Society of Antiquaries, London; and alſo a member of many of the academies of ſciences and learning in different parts of Europe. In compliment to theſe honorary diſtinctions from ſuch learned bodies, he preſented elegant coloured copies of all his works to the Royal College of Phyſicians, the Royal Society, and Society of Antiquarians, and to the Britiſh muſeum: alſo to the Royal Academy of Sciences at Paris, from whom he received the moſt polite and obliging letter of thanks by their then ſecretary Monſieur Defouchy. His collection of drawings, which amounted to upwards of 900, were purchaſed by the earl of Bute. They contain a great number of Britiſh as well as foreign birds, and other animals hitherto not accurately delineated or deſcribed. After the publication of the laſt work, being arrived at his 70th year, he found his ſight begin to fail, and his hand loſt its wonted ſteadineſs. He retired from public employment to a little houſe which he purchaſed at Plaiſtow; previous to which, he diſpoſed of all the copies, as well as plates, of his works. The converſation of a few ſelect friends, and the peruſal of a few ſelect books, were the amuſement of the evening of his life; and now and then he made an excurſion to ſome of the principal cities in England, particularly to Briſtol, Bath, Exeter, and Norwich. Some years before his death, the alarming depredation of a cancer, which baffled all the efforts of medical ſkill, deprived him of the ſight of one of his eyes: he alſo ſuffered much from the ſtone, to which at different periods of his life he had been ſubject. But in the ſevereſt paroxyſms of pain, he was ſcarcely known to utter a ſingle complaint. Having completed his 80th year, emaciated with age and ſickneſs, he died, deſervedly lamented, on the 23d of July 1773.

EDYSTONE, a lighthouſe in the Britiſh channel, built on rocks of the ſame name, which are ſuppoſed to have got this appellation from the great variety of contrary ſets of the current among them, both upon the tide of flood and the tide of ebb. They are ſituated nearly ſouth-

ſouth-ſouth-weſt from the middle of Plymouth ſound, according to the true meridian; and the diſtance, as nearly as can be collected, is twelve miles and a half; and from the ſame point in the Sound to the Jetty Head, called the Barbican, in the port of Plymouth, is a mile and a half more, which makes the diſtance of the Edyſtone from the port of Plymouth to be nearly fourteen miles.

"The promontory called Ram Head is the neareſt point of land to the Edyſtone, which bears from thence ſouth ſcarcely one point weſt, diſtant about ten miles, and conſequently by the compaſs is nearly ſouth-weſt by ſouth.—Thoſe rocks are nearly in a line, but ſomewhat within that line 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 muſt, before a lighthouſe was eſtabliſhed thereon, have been very dangerous, and often fatal to ſhips under ſuch circumſtances: and many rich ſhips and other veſſels have, in former times, been actually loſt upon thoſe rocks, particularly ſuch as were homeward-bound from foreign parts; it being even now a common thing, in foggy and thick hazy weather, for homeward-bound ſhips from long foreign voyages to make the Edyſtone lighthouſe as the firſt point of land of Great Britain; ſo that in the night, and nearly at high water, when the whole range of theſe rocks are covered, the moſt careful mariner might run his ſhip upon them, if nothing was placed there by way of warning.

"The many fatal accidents which ſo frequently happened, made it a thing very deſirable to have a lighthouſe built thereon, and that for many years before any competent undertaker appeared. At length, however, we learn, that in the year 1696 Mr Henry Winſtanley, of Littlebury in the county of Eſſex, Gent. was not only hardy enough to undertake it, but was furniſhed with the neceſſary powers to put it in execution. This, it is ſuppoſed, was done in virtue of the general powers lodged in the maſter, wardens, and aſſiſtants of the Trinity-houſe at Deptford Strond to erect ſea marks, &c. by a ſtatute of Queen Elizabeth, whereby they are impowered 'to erect and ſet up beacons, marks, and ſigns for the ſea, needful for avoiding the dangers; and to renew, continue, and maintain the ſame.' But whether Mr Winſtanley was a proprietor or ſharer of the undertaking under the Trinity-houſe, or only the directing engineer employed in the execution, does not now appear.

"This gentleman 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 middle of 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 was 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. (A).

"The lighthouſe Mr Winſtanley built was begun in the year 1696, and was more than four years in building; not, (ſays the architect), for the greatneſs of the work, but for the difficulty and danger in getting backwards and forwards to the place. The difficulties were many, and the dangers not leſs. At length, in the third year, all the work was raiſed, which to the vane was eighty feet. Being all finiſhed, with the lantern, and all the rooms that were in it, they ventured to lodge there ſoon after midſummer, for the greater diſpatch of the work. But the firſt night the weather came bad, and ſo continued, that it was eleven days before any boats could come near them again, and not being acquainted with the height of the ſea riſing, they were almoſt all the time drowned with wet, and their proviſions in as bad a condition, though they worked night and day to make ſhelter for themſelves. In this ſtorm they loſt ſome of their materials, although they did what they could to ſave them; but the boat then returning, they all left the houſe to be refreſhed on ſhore; and as ſoon as the weather permitted, they returned again and finiſhed all, and put up the light on the 14th of November 1698; which being ſo late in the year, it was three days before Chriſtmas before they had relief to get on ſhore again, and were almoſt at the laſt extremity for want of proviſions; but by good providence, then two boats came with proviſions, and the family that was to take care of the light.

"The fourth year, finding in the winter the effects the ſea had upon the houſe, and burying the lantern at times, although more than 60 feet high; Mr Winſtanley early in the ſpring encompaſſed the building with a new work of four feet thickneſs from the foundation, making all ſolid near 20 feet high; and taking down the upper part of the firſt building, and enlarging every part in its proportion, he raiſed it forty feet higher than it was at firſt; and yet the ſea, in time of ſtorms, flew up in appearance 100 feet (B) above the vane; and at times covered half the ſide of the houſe and the lantern as if they were under water.

"On the finiſhing this building, it was generally ſaid, that in the time of hard weather, ſuch was the height of

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(A) It appears that the exhibition of theſe water-works continued ſome years after the death of Mr Winſtanley, as they were exiſting in the month of September 1709, being mentioned in the Tatler of that date.

(B) Mr Smeaton ſays this is ſhort of its real height 50 feet.

of the ſeas, that it was very poſſible for a ſix-oared boat to be lifted up upon a wave, and driven through the open gallery of the lighthouſe.

"In November 1703, the fabric wanted ſome repairs, and Mr Winſtanley went down to Plymouth to ſuperintend the performance of them. The opinion of the common people was, that the building would not be of long duration. Mr Winſtanley, however, held different ſentiments. Being amongſt his friends previous to his going off with his workmen on account of thoſe reparations, the danger was intimated to him; and it was ſaid, that one day or other the lighthouſe would certainly be overſet. To this he replied, "He was ſo 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 upon the ſtructure."

"In this wiſh he was ſoon gratified; for while he was there with his workmen and light-keepers, that dreadful ſtorm began which raged the moſt violently upon the 26th 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, when the ſtorm was abated, nothing of the lighthouſe was to be ſeen. The following account of its deſtruction was printed at the time, by Daniel Defoe in a book entitled *The Storm:*"

"The loſs of the lighthouſe called the Edyſtone, at Plymouth, is another article of which we never heard any particulars, other than this, that at night it was ſtanding, and in the morning all the upper part of the gallery was blown down, and all the people in it periſhed, and, by a particular misfortune, Mr Winſtanley the contriver of it; a perſon whoſe loſs is very much regretted by ſuch as knew him, as a very uſeful man to his country. The loſs of that lighthouſe is alſo a conſiderable damage, as it is very doubtful whether it will ever be attempted again; and it was a great ſecurity to the ſailors, many a good ſhip having been loſt there in former times.

"It was very remarkable, that as we are informed, at the ſame time the lighthouſe aforeſaid was blown down, the model of it in Mr Winſtanley's houſe at Littlebury in Eſſex, above 200 miles from the lighthouſe, fell down and was broke to pieces.

"At Plymouth they felt a full proportion of the ſtorm in its utmoſt fury. The Edyſtone has been already mentioned, but it was a double loſs, in that the lighthouſe had not been long down when the *Winchelſea*, a homeward-bound Virginia-man, was ſplit upon the rock where that building ſtood, and moſt of her men drowned."

"The great utility of Mr Winſtanley's lighthouſe had been ſufficiently evident to thoſe for whoſe uſe it was erected; and the loſs of the Winchelſea Virginia-man, before-mentioned, proved a powerful incentive to ſuch as were intereſted, to exert themſelves in order for its reſtoration. It was not, however, begun ſo ſoon as might have been expected. In ſpring of the year 1706, an act of parliament paſſed enabling the Trinity houſe to rebuild, but it was no earlier than July that it was begun. The undertaker was a Captain Lovell or Lovett, who took it for the term of ninety nine years, commencing from the day that a light ſhould be exhibited.

"To enable him to fulfil his undertaking, Captain Lovett engaged Mr John Rudyerd to be his engineer or architect; and his choice, though Mr Rudyerd does not appear to have been bred to any mechanical buſineſs or ſcientifical profeſſion, was not ill made. He at that time kept a linen-draper's ſhop upon Ludgate-hill. His want of experience, however, was in a degree aſſiſted by Mr Smith and Mr Notcutt, both ſhip-wrights from the king's yard at Woolwich, who worked with him the whole time he was building the lighthouſe.

"It is not very material in what way this gentleman became qualified for the execution of the work: it is ſufficient that he directed the performance thereof 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, they ſhew a bad taſte, and betray ignorance of its firſt principle, judgment.

"The building was begun in July 1706, a light was put up in it the 28th July 1708, and it was completely finiſhed in 1709. The quantity of materials expended in the conſtruction, was 500 tons of ſtone, 1200 tons of timber, 80 tons of iron, and 35 tons of lead; of trenails, ſcrews, and rack-bolts 2500 each.

"Louis XIV. being at war with England during the proceeding with this building, a French privateer took the men at work upon it, together with their tools, and carried them to France; and the captain was in expectation of a reward for the atchievement. While the captives lay in priſon, the tranſaction reached the ears of that monarch. He immediately ordered them to be releaſed, and the captors to be put in their place; declaring, that though he was at war with England, he was not at war with mankind; he therefore directed the men to be ſent back to their work with preſents; obſerving, that the Edyſtone light-houſe was ſo ſituated, as to be of equal ſervice to all nations having occaſion to navigate the channel that divides France from England.

In the year 1715 Captain Lovett being dead, his property in the Edyſtone lighthouſe was ſold before a maſter in chancery to Robert Weſton, Eſq. —— Noyes, Eſq. of Gray's-Inn; and —— Cheetham, Eſq. an alderman of Dublin, who divided the ſame into eight ſhares. After a few years ſome repairs were found wanting; and in 1723, Mr Rudyerd being, we ſuppoſe, then dead, Mr John Holland, foreman ſhip-wright in the dock-yard at Plymouth, became overſeer and director of the neceſſary reparations; which office he again executed in 1734.

"The cataſtrophe of this lighthouſe took place on the 2d December 1755, when the light-keeper upon watch, about two o'clock in the morning, went into the lantern as uſual to ſnuff the candles; he found the whole in a ſmoke; and upon opening the door of the lantern into the balcony, a flame inſtantly burſt from the inſide of the cupola: he immediately endeavoured to alarm his companions; but they being in bed, and aſleep, were not ſo ready in coming to his aſſiſtance as the occaſion required. As there were always ſome leather buckets kept in the houſe, and a tub of water in the lantern, he attempted to extinguiſh the fire by throwing water from the balcony upon the outſide cover of lead. By this time his companions arriving, he encouraged them to fetch up water with the buckets from the ſea; but the height of the place, added to the conſternation which muſt attend ſuch an unexpected event, rendered their efforts fruitleſs. The flames gathered ſtrength every moment; the poor man with every exertion, having the water to throw four yards higher than himſelf, found himſelf unable to ſtop the progreſs of the conflagration, and was obliged to deſiſt.

"As he was looking upward with the utmoſt attention to ſee the effect of the water thrown, a poſition which, phyſiognomiſts tell us, occaſions the mouth naturally to be a little open, a quantity of lead diſſolved by the heat of the flames ſuddenly ruſhed like a torrent from the roof, and fell upon his head, face, and ſhoulders, and burnt him in a dreadful manner: from this moment he had a violent internal ſenſation, and imagined that a quantity of this lead had paſſed his throat, and got into his body. Under this violence of pain and anxiety, as every attempt had proved ineffectual, and the rage of the flames was increaſing, it is not to be wondered that the terror and diſmay of the three men increaſed in proportion; ſo that they all found themſelves intimidated, and glad to make their retreat from the immediate ſcene of horror into one of the rooms below. They therefore deſcended as the fire approached, with no other proſpect than that of ſecuring their immediate ſafety, with ſcarcely any hopes of being ſaved from deſtruction.

"How ſoon the flames were ſeen on the ſhore is uncertain; but early in the morning they were perceived by ſome of the Cawſand fiſhermen, and intelligence thereof given to Mr Edwards, of Rame, in that neighbourhood, a gentleman of ſome fortune, and more humanity, who immediately ſent out a fiſhing-boat and men to the relief of the diſtreſſed objects in the lighthouſe (D).

"The boat and men got thither about ten o'clock, after the fire had been burning full eight hours; in which time the three light-keepers were not only driven from all the rooms and the ſtaircaſe, but, to avoid the falling of the timber and red-hot bolts, &c. upon them, they were found ſitting in the hole or cave on the eaſt ſide of the rock under the iron ladder, almoſt in a ſtate of ſtupefaction; it being then low water.

"With much difficulty they were taken off; when finding it impoſſible to do any further ſervice, they haſtened to Plymouth. No ſooner were they ſet on ſhore, than one of the men ran away, and was never afterwards heard of. This circumſtance, though it might lead to ſuſpicions unfavourable to the man, Mr Smeaton is of opinion ought not to weigh any thing againſt him, as he ſuppoſes it to have ariſen from a panic which ſometimes ſeizes weak minds, and prevents their acting agreeable to the dictates of right reaſon.

"It was not long before the dreadful news arrived at Plymouth. Alderman Tolcher and his ſon immediately went to ſea, but found it impoſſible to do any thing with effect. Admiral Weſt alſo, who then lay in Plymouth ſound, ſent a ſloop properly armed, with a boat and an engine therein, which alſo carried out Mr Jeſſop the ſurveyor. This veſſel arrived early in the day. Many attempts were made to play the engine, but the agitation of the ſea prevented it from being employed with ſucceſs. On the ſucceeding days the fire ſtill continued, and about the 7th the deſtruction of the whole was completed.

"The man who has been mentioned already was named Henry Hall, of Stonehouſe, near Plymouth, and though aged 94 years, being of a good conſtitution, was remarkably active, conſidering his time of life. He invariably told the ſurgeon who attended him, Mr Spry (now Dr Spry) of Plymouth, that if he would do any thing effectual to his recovery, he muſt relieve his ſtomach from the lead which he was ſure was within him; and this he not only told Dr Spry, but all thoſe about him, though in a very hoarſe voice, and the ſame aſſertion he made to Mr Jeſſop.—The reality of the aſſertion ſeemed, however, then incredible to Dr Spry, who could ſcarcely ſuppoſe it poſſible that any human being could exiſt after receiving melted lead into the ſtomach; much leſs that he ſhould afterwards be able to bear towing through the ſea from the rock, and alſo the fatigue and inconvenience from the length of time he was in getting on ſhore before any remedies could be applied. The man, however, did not ſhew any ſymptoms of being much worſe or better until the ſixth day after the accident, when he was thought to mend: he conſtantly took his medicines, and ſwallowed many things both liquid and ſolid, till the tenth or eleventh day; after which he ſuddenly grew worſe; and on the twelfth, being ſeized with cold ſweats and ſpaſms, he ſoon after expired.

His body was opened by Dr Spry, and in the ſtomach was found a ſolid piece of lead of a flat oval form, which weighed 7 ounces and 5 drachms. So extraordinary a circumſtance appearing to deſerve the notice of the philoſophical world, an account of it was ſent to the Royal Society, and printed in the 49th volume of their tranſactions, p. 477.

"The lighthouſe being thus demoliſhed, the proprietors immediately turned their thoughts to the rebuilding of it. They had in it a term of near half a century, but ſome ſhares being ſettled by the marriage articles of one of the parties, ſome impediments aroſe which could not be overcome without the aid of parliament, which was ſoon obtained. To one of the partners, Robert Weſton, Eſq. the management of the buſineſs was committed,

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(D) This benevolent gentleman caught a cold on this occaſion which coſt him his life.

committed, and he thought it requiſite to apply to the earl of Macclesfield, then preſident of the Royal Society, to recommend a proper perſon to ſuperintend the work. On communicating the object of his viſit, Lord Macclesfield told him, that there was one of the Royal Society whom he would venture to recommend to the buſineſs; yet that the moſt material part of what he knew of him was, his having within the compaſs of the laſt ſeven years recommended himſelf to the Society by the communication of ſeveral mechanical inventions and improvements; and though he had at firſt made it his buſineſs to execute things in the inſtrument way (without having been bred to the trade) yet on account of the merit of his performances, he had been choſen a member of the Society, and that for about three years paſt, having found the buſineſs of a philoſophical inſtrument-maker not likely to afford an adequate recompence, he had wholly applied himſelf to ſuch branches of mechanics as were wanted by the proprietors; that he was then ſomewhere in the north of England, executing a work: and that as he had always ſatisfied his employers, he would not be likely to undertake what he could not perform.

"The perſon thus deſcribed was Mr Smeaton, who was written to by Mr Benjamin Wilſon the painter, laconically informing him, that he was the perſon fixed upon to rebuild the Edyſtone lighthouſe. But this intimation conveying to his mind no more than a mere notice that he might, in common with others, deliver in propoſals to repair it, not knowing then that it was entirely deſtroyed, it afforded but little ſatisfaction, and he returned only a cool anſwer. Mr Wilſon's reply was ſtill more laconic: That the demolition was total, and that as Nathan ſaid unto David, 'Thou art the man.'

"Mr Smeaton immediately diveſted himſelf of his engagements in the north, and arrived in London the 23d of February 1756, and had an interview next day with the principal proprietor. The mode of rebuilding then became the ſubject of their deliberations, which at length ended in a determination to rebuild it with ſtone.

"On the 5th of April Mr Smeaton firſt ſet his foot on the Edyſtone rock. He immediately began to take his meaſures for proceeding on the work. He made all the neceſſary inquiries on the ſpot, and in the neighbourhood. He conſidered the nature and quality of the ſtone proper to be uſed, and from whence it might be obtained at the beſt and cheapeſt rates. He viſited the quarries at Beare in Devonſhire, and the iſle of Portland, and from the latter of theſe places he at length determined to be ſupplied with his materials.

"Having proceeded thus far, he returned to London, and had a meeting with the proprietors, who, for reaſons highly honourable to them, confirmed their determination to rebuild with ſtone. He accordingly prepared his models and deſigns, which were approved by his employers, and directed to be exhibited to the lords of the Admiralty, and the maſters of the Trinity houſe. To the former they were ſhewn; but the latter having fixed their time for viewing them at ſo diſtant a day as to hazard the progreſs of the work, he determined to ſet off for Plymouth without their inſpection.

"He arrived at Plymouth the 23d of July, 1756, and, immediately began his operations. He appointed his aſſiſtants, hired his men, ſettled their wages, and drew up rules for their conduct. He alſo hired a piece of ground for a work-yard. On the 3d of Auguſt they went off to the rock, and continued to work as long as the weather would permit. The next winter Mr Smeaton determined to continue at Plymouth, to go through a courſe of experiments on cements. On the 3d of June 1757, the works were reſumed, and on the 12th the firſt ſtone was fixed. From this time the erection proceeded with regularity and diſpatch, and with no other interruptions than what might be expected from the nature of the work, until the 9th of October 1759, when, after innumerable difficulties and dangers, a happy period was put to the 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.

"It now remained only to wait for a ſtorm to try the durability of the building. The hard weather of 1759, 1760, and 1761, appeared to make no impreſſion. The year 1762 was uſhered in by 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 lighthouſe is now ſtanding, it will ſtand to the day of judgment;" and in reality, from this time its exiſtence has been ſo entirely laid out of men's minds, that whatever ſtorms have happened ſince, no inquiry has ever been made concerning it. So confident was a very intelligent friend of Mr Smeaton's of its durability, that he wrote to him, that he might for ever rid himſelf of any uneaſy thought of the houſe as to its danger from wind and ſea.

"The lighthouſe is attended by three men, who receive 25l. a-year each, with an occaſional abſence in ſummer. Formerly there were only two, who watched alternately four hours and four hours; but one being taken ill and dying, the neceſſity of an additional hand became apparent. In this dilemma, the living man found himſelf in an awkward ſituation. Being apprehenſive if he tumbled the dead body into the ſea, which was the only way in his power to diſpoſe of it, he might be charged with murder, he was induced for ſome time to let the dead body lie, in hopes that the boat might be able to land, and relieve him from the diſtreſs he was in. By degrees the body became ſo offenſive, that it was not in his power to get quit of it without help; for it was near a month before the attending boat could effect a landing; and then it was not without the greateſt difficulty that it could be done, when they did land. To ſuch a degree was the whole building filled with the ſtench of the corpſe, that it was all they could do to get the dead body diſpoſed of and thrown into the ſea, and it was ſome time after that before the rooms could be freed from the noiſome ſtench that was left.

"It is ſaid, that while two light-keepers only were employed, on ſome diſguſt they forbore to ſpeak to each other. A perſon obſerving to one of them how happy they might live in their ſtate of retirement, "Yes," ſays the man, "very comfortably, if we could have the uſe of our tongues; but it is now a full month ſince my partner and I have ſpoke to each other."

"To theſe anecdotes we ſhall add one more, and conclude. A ſhoemaker was carrying out to the lighthouſe in order to be light-keeper. In their way, ſays the ſkipper to him, "How happens it, friend Jacob, that you ſhould chuſe to go out to be a light-keeper, when you can on ſhore (as I am told) earn half-a-crown and three ſhillings a-day in making leathern hoſe (leathern pipes ſo called); whereas the light-keeper's ſalary is but 25l. a-year, which is ſcarce ten ſhillings a-week." Says the ſhoemaker, "I go to be a light-keeper, becauſe I don't like confinement." After this anſwer had produced its ſhare of merriment, he at laſt explained himſelf by ſaying, that he did not like to be confined to work.

"The whole time between the firſt ſtroke upon the rock and leaving the lighthouſe complete, was three years nine weeks and three days; from the 5th of December 1755, to exhibiting the light October 1759, was three years ten months and ſixteen days; and the whole time of working on the rock 111 days 10 hours" (E).

EEL. See MURÆNA, ICHTHYOLOGY *Index*.

Eel-Fiſhing. See BOBBING and SNIGGLING.

The ſilver eel may be catched with ſeveral ſorts of baits, as powdered beef, garden worms, minnows, hens guts, fiſh garbage, &c. The moſt proper time for taking them is in the night, faſtening your line to the bank ſides, with your laying hook in the water: or a line may be thrown with good ſtore of hooks, baited and plumbed, with a float to diſcover where the line lies, that they may be taken up in the morning.

Microſcopic EELS. See ANIMALCULE, Nº 8.

EELS *in vinegar*, are ſimilar to thoſe in ſour paſte. The taſte of vinegar was formerly thought to be occaſioned by the biting of theſe little animals, but that opinion has been juſtly long exploded. Mentzelius ſays, he has obſerved the actual transformation of theſe little creatures into flies.

EEL *Spear*, a forked inſtrument with three or four jagged teeth, uſed for catching eels: that with the four teeth is beſt, which they ſtrike into the mud at the bottom of the river, and if it ſtrike againſt any eels it never fails to bring them up.

EFFARE', or EFFRAYE', in *Heraldry*, a term applied to a beaſt rearing on its hind legs, as if it were frighted or provoked.

EFFECT, in a general ſenſe, is that which reſults from, or is produced by, any cauſe. See CAUSE.

EFFEMINATE, womaniſh, unmanly, voluptuous.

EFFEMINATE (*effeminati*), according to the vulgate, are mentioned in ſeveral places of Scripture. The word is there uſed to ſignify ſuch as were conſecrated to ſome profane god, and proſtituted themſelves in honour of him. The Hebrew word *hadeſh*, tranſlated *effeminatus*, properly ſignifies *conſecrated*, and hence was attributed to thoſe of either ſex, who publicly proſtituted themſelves in honour of Baal and Aſtarte. Moſes expreſsly forbids theſe irregularities among the Iſraelites; but the hiſtory of the Jews ſhows, that they were notwithſtanding frequently practiſed. Levit. xxiii. 18.

EFFENDI, in the Turkiſh language, ſignifies *maſter*: and accordingly is a title very extenſively applied; as to the mufti and emirs, to the prieſts of moſques, to men of learning, and of the law. The grand chancellor of the empire is called *reis-effendi*.

EFFERVESCENCE, an inteſtine motion excited betwixt the parts of two bodies of different natures, when they reciprocally diſſolve each other. Efferveſcences are commonly attended with bubbles, vapours, ſmall jets of the liquid, and a hiſſing noiſe; and theſe phenomena are occaſioned by the air which at that time diſengages itſelf. Sometimes alſo they are accompanied with a great degree of heat, from the decompoſition of ſome ſubſtances and the formation of new compounds.

Formerly the word *fermentation* was alſo applied to efferveſcences; but now that word is confined to the motion naturally excited in animal and vegetable matters, and from which new combinations among their principles take place.

EFFIGY, the portrait, figure, or exact repreſentation of a perſon.

EFFIGY, is alſo uſed for the print or impreſſion of a coin, repreſenting the prince's head who ſtruck it.

EFFIGY, *to execute or degrade in*, denotes the execution or degradation of a condemned contumacious criminal, who cannot be apprehended or ſeized. In France, they hang a picture on a gallows or gibbet; wherein is repreſented the criminal, with the quality or manner of the puniſhment: at the bottom is written the ſentence of condemnation. Such perſons as are ſentenced to death are executed in effigy.

EFFLORESCENCE, among phyſicians, the ſame with exanthema. See EXANTHEMA.

EFFLORESCENCE, in *Chemiſtry*, denotes the formation of a kind of mealy powder on the ſurface of certain bodies. Effloreſcence is occaſioned either by decompoſition or drying. The effloreſcence which happens to cobalt and martial pyrites is of the firſt; and that obſerved on the cryſtals of ſoda, Glauber's ſalt, &c. of the latter kind. An effloreſcence is ſometimes alſo a ſpecies of cryſtallization; ſuch as the beautiful vegetations which ſhoot up from different ſaline ſubſtances. See CRYSTALLIZATION.

EFFLORESCENTIA, in *Botany*, (from *effloreſco* to bloom); the preciſe time of the year and month in which every plant ſhows its firſt flowers.

Some plants flower twice a-year, as is common between the tropics; others oftener, as the monthly roſe. The former are called by botaniſts *biferæ*; the latter, *multiferæ*.

The time of flowering is determined by the degree of heat which each ſpecies requires. Mezereon and ſnowdrop produce their flowers in February; primroſe, in the beginning of March; the greater number of plants, during the month of May; corn, and other grain, in the beginning of June; the vine, in the middle of the ſame month; ſeveral compound flowers, in the months of July and Auguſt; laſtly, meadow-ſaffron flowers in the month of October, and announces the ſpeedy approach of winter.

Graſs of Parnaſſus always flowers about the time of cutting

(E) This account is extracted from a Narrative of the Building, and a Deſcription of the Conſtruction of the Edyſtone Lighthouſe with Stone. By John Smeaton, Civil Engineer, F. R. S.

Efflorescence
||
Egeria.

cutting down the hay; and in Sweden, the different ſpecies of thiſtle, mountain lettuce, ſuccory, and balſam, ſeldom flower till after the ſummer ſolſtice: the country men even know, as by a kalendar, that the ſolſtice is paſt when theſe plants begin to produce their flowers.

The temperature of the ſeaſons has a great influence both in accelerating and retarding the flowering of plants. All plants are earlier in warm countries; hence ſuch as are cultivated out of their native ſoil, never flower till the heat of the climate, or ſituation into which they are removed, is equal to that under the influence of which they produced flowers in their own country. For this reaſon, all exotics from warm climates are later in this country than many plants which it naturally produces.

In general, we may obſerve, that the plants of the coldeſt countries, and thoſe produced on the mountains in all climates, being of equal temperature, flower about the ſame time, viz. during our ſpring in Europe.

Plants that grow betwixt the tropics, and thoſe of temperate climates, flower during our ſummer.

Plants of temperate climates, ſituated under the ſame parallel of latitude with certain parts of Europe, but removed much farther to the weſt, ſuch as Canada, Virginia, and Miſſiſſippi, do not produce flowers till autumn.

Plants of temperate climates in the oppoſite hemiſphere to Europe, flower during our winter, which is the ſummer of theſe regions.

Linnæus and Adanſon have given a ſketch of the different times in which plants flower at Upſal and Paris.

EFFLUVIUM, in *Phyſiology*, a term much uſed by philoſophers and phyſicians, to expreſs the minute particles which exhale from moſt, if not all, terreſtrial bodies, in form of ſenſible vapours.

EFFRONTES, in church hiſtory, a ſect of heretics, in 1534, who ſcraped their forehead with a knife till it bled, and then poured oil into the wound. This ceremony ſerved them inſtead of baptiſm. They are likewiſe ſaid to have denied the divinity of the Holy Spirit.

EFFUSION, the pouring out of any liquid thing with ſome degree of force. In the ancient heathen ſacrifices there were divers effuſions of wine and other liquors, called *libations*.

Effusion, or Fusion, in *Aſtronomy*, denotes that part of the ſign Aquarius, repreſented on celeſtial globes and planiſpheres, by the water iſſuing out of the urn of the water-bearer.

EFT, or water lizard. See Lacerta, Erpetology *Index*.

EGERIA, or ÆGERIA, a nymph held in great veneration by the Romans. She was courted by Numa Pompilius; and, according to Ovid, ſhe became his wife. This prince frequently viſited her; and that he might introduce his laws and new regulations into the ſtate, he ſolemnly declared before the Roman people, that they were previouſly ſanctified and approved by the nymph Egeria. Ovid ſays, that Egeria was ſo diſconſolate at the death of Numa, that ſhe melted into tears, and was changed into a fountain by Diana. She is reckoned by many as a goddeſs who preſided over the pregnancy of women; and ſome maintain that ſhe is the ſame as Lucina.

Egg.

EGG, in *Phyſiology*, a body formed in certain females, in which is contained an embryo or fœtus of the ſame ſpecies, under a cortical ſurface or ſhell. The exterior part of an egg is the ſhell; which in a hen, for inſtance, is a white, thin, and friable cortex, including all the other parts. The ſhell becomes more brittle by being expoſed to a dry heat. It is lined everywhere with a very thin but a pretty tough membrane, which dividing at, or very near, the obtuſe end of the egg, forms a ſmall bag, where only air is contained. In new laid eggs this follicle appears very little, but becomes larger when the egg is kept.

Within this are contained the albumen or white, and the vitellus or yolk; each of which have their different virtues.

The albumen is a cold, viſcous, white liquor in the egg, different in conſiſtence in its different parts. It is obſerved, that there are two diſtinct albumens, each of which is encloſed in its proper membrane. Of theſe one is very thin and liquid: the other is more denſe and viſcous, and of a ſomewhat whiter colour; but, in old and ſtale eggs, after ſome days incubation, inclining to a yellow. As this ſecond albumen covers the yolk on all ſides, ſo it is itſelf ſurrounded by the other external liquid. The albumen of a fecundated egg is as ſweet and free from corruption, during all the time of incubation, as it is in new laid eggs; as is alſo the vitellus. As the eggs of hens conſiſt of two liquors ſeparated one from another, and diſtinguiſhed by two branches of umbilical veins, one of which goes to the vitellus, and the other to the albumen; ſo it is very probable that they are of different natures, and conſequently appointed for different purpoſes.

When the vitellus grows warm with incubation, it becomes more humid, and like melting wax or fat; whence it takes up more ſpace. For as the fœtus increaſes, the albumen inſenſibly waſtes away and condenſes: the vitellus, on the contrary, ſeems to loſe little or nothing of its bulk when the fœtus is perfected, and only appears more liquid and humid when the abdomen of the fœtus begins to be formed.

The chick in the egg is firſt nouriſhed by the albumen: and when this is conſumed, by the vitellus, as with milk. If we compare the chalazæ to the extremities of an axis paſſing through the vitellus, which is of a ſpherical form, this ſphere will be compoſed of two unequal portions, its axis not paſſing through its centre; conſequently, ſince it is heavier than the white, its ſmaller portion muſt always be uppermoſt in all poſitions of the egg.

The yellowiſh white round ſpot, called *cicatricula*, is placed on the middle of the ſmaller portion of the yolk; and therefore, from what has been ſaid in the laſt paragraph, muſt always appear on the ſuperior part of the vitellus.

Not long before the excluſion of the chick, the whole yolk is taken into its abdomen; and the ſhell, at the obtuſe end of the egg, frequently appears cracked ſome time before the excluſion of the chick. The chick is ſometimes obſerved to perforate the ſhell with its

its beak. After excluſion, the yolk is gradually waſted, being conveyed into the ſmall guts by a ſmall duct.

Eggs differ very much according to the birds that lay them, as to their colour, form, bigneſs, age, and the different way of dreſſing them: thoſe moſt uſed in food are hens eggs; of which, ſuch as are new laid are beſt.

As to the preſervation of eggs, it is obſerved that the egg is always quite full when it is firſt laid by the hen; but from that time it gradually becomes leſs and leſs ſo, to its decay: and however compact and cloſe its ſhell may appear, it is nevertheleſs perforated with a multitude of ſmall holes, though too minute for the diſcernment of our eyes, the effect of which is a daily decreaſe of matter within the egg, from the time of its being laid; and the perſpiration is much quicker in hot weather than in cold.

To preſerve the egg freſh, there needs no more than to preſerve it full, and ſtop its tranſpiration; the method of doing which is, by ſtopping up thoſe pores with matter which is not ſoluble in watery fluids: and on this principle it is, that all kinds of varniſh, prepared with ſpirit of wine, will preſerve eggs freſh for a long time, if they are carefully rubbed all over the ſhell: tallow, or mutton fat, is alſo good for this purpoſe; for ſuch as are rubbed over with this, will keep as long as thoſe coated over with varniſh.

Artificial Method of Hatching Eggs. See HATCHING.

EGINA. See ÆGINA.

EGINHART, ſecretary to the emperor Charles the Great, was a German. He is the moſt ancient hiſtorian of that nation, and wrote very eloquently for a man of the 9th century. It is ſaid, that he inſinuated himſelf ſo well into the favour of Imma, daughter to Charles the Great, that he obtained from her whatever he deſired. Charles the Great, having found out the intrigue, did not do as Auguſtus, who is thought to have baniſhed Ovid becauſe he believed him to be too much favoured by Julia; for he married the two lovers together, and gave them a fine eſtate in land.

EGLANTINE. See ROSA, BOTANY *Index*.

EGLON, a king of the Moabites, who oppreſſed the Iſraelites for 18 years (Judges iii. 12—14.). Calmet confounds this ſervitude of the Hebrews with that under Chuſan-riſhathaim, making it to ſubſiſt only eight years, from the year of the world 2591 to 2599; whereas this ſervitude under Eglon laſted 18 years, and commenced in the year of the world 2661, and 62 years after they had been delivered by Othniel from the ſubjection of Chuſan-riſhathaim.

EGRA, a town of Bohemia, formerly imperial, but now ſubject to the houſe of Auſtria. It contains a great number of able artificers, and is famous for its mineral waters. Wallenſtein, the emperor's general, was aſſaſſinated here in 1634. The French became maſters of this town in 1741; but afterwards being blocked up, they were forced to capitulate on September 7th, 1743. It is looked upon as a town of the greateſt conſequence in Bohemia, except Prague. It is ſeated on a river of the ſame name, in E. Long. 12. 30. N. Lat. 50. 21.

EGRET, in *Ornithology*, a ſpecies of ardea. See ARDEA, ORNITHOLOGY *Index*.

EGYPT, an extenſive country of Africa, lying between 30° and 36° of eaſt longitude, and between 21° and 31° of north latitude. It is bounded by the Mediterranean on the north; by the Red ſea and iſthmus of Suez, which divide it from Arabia, on the eaſt; by Abyſſinia or Ethiopia, on the ſouth; and by the deſerts of Barca and Nubia, on the weſt; being 600 miles in length from north to ſouth, and from 100 to 200 in breadth from eaſt to weſt.

1
Different names.

As a nation, the Egyptians may with juſtice lay claim to as high antiquity as any in the world. The country was moſt probably peopled by Mizraim the ſon of Ham and grandſon of Noah.—By its ancient inhabitants it was called *Chemia*, and is ſtill called *Chemi* in the language of the *Copts* or native Egyptians; and this name it is ſuppoſed to have received from Ham the ſon of Noah. In ſcripture, we find it moſt generally named *Miſraim;* though in the Pſalms it is ſtyled the *land of Ham*.—To us it is beſt known by the name *Egypt*, the etymology of which is more uncertain.—Some derive it from *Ægyptus*, a ſuppoſed king of the country: others ſay it ſignifies no more than "the land of the *Copts*;" *Aia* in Greek ſignifying a country, and *Æcoptos* being eaſily ſoftened into *Ægyptus*.—The moſt probable opinion, however, ſeems to be, that it received its name from the blackneſs of its ſoil, and the dark colour both of its river and inhabitants: for ſuch a blackiſh colour is by the Greeks called *ægyptios* from *gyps*, and *ægyps* "a vulture;" and by the Latins, *ſubvulturius*. For the ſame reaſon, other names of a ſimilar import have been given to this country by the Greeks; ſuch as *Aeria* and *Melambolus:* the river itſelf was called *Melo* or *Melas;* by the Hebrews, *Shihor;* and by the Europeans, *Siris;* all of which ſignify "black."

Ancient Egypt is by ſome divided into two parts, the Upper and Lower Egypt: by others into three, the Upper Egypt, properly ſo called, or *Thebais;* the Middle Egypt, or *Heptanomes;* and the Lower Egypt, the beſt part of which was the *Delta*, or that ſpace encompaſſed by the branches of the Nile. See THEBAIS, &c.

The Egyptians, like the Chineſe, pretend to an exceſſive antiquity, pretending to have records for ten, twenty, or even fifty thouſand years. Thus their hiſtory is ſo much involved in obſcurity and fable, that for many ages it muſt be paſſed over in ſilence.—The firſt mortal king whom the Egyptians own to have reigned in that country, was *Menes* or *Menas*. At what time he reigned, it would be to a very little purpoſe to inquire. He had been preceded, however, by a ſet of immortals, who it ſeems left him the kingdom in a very bad ſituation: for the whole country, except Thebais, was a moraſs; the people alſo were entirely deſtitute of religion, and every kind of knowledge which could render their life comfortable and happy. Menes diverted the courſe of the Nile, which before that time had waſhed the foot of a ſandy mountain near the borders of Libya, built the city of Memphis, inſtructed his ſubjects, and did other things of a ſimilar kind which are uſually attributed to the founders of kingdoms.

2
Invaded by the ſhepherds.

From the time of Menes, the Egyptian chronology is filled with a liſt of 330 kings, who reigned 1400 years, but did nothing worthy of notice.—The firſt diſtinct piece of hiſtory we find concerning Egypt, is the

the irruption of the *Shepherds*, by whom the country was ſubdued; but whether this revolution happened during the vaſt interval of indolence above mentioned, or before or after, cannot be known. The affair is thus related by Manetho. It happened, in the reign of Timaus king of Egypt, that God being diſpleaſed with the Egyptians, they ſuffered a great revolution: for a multitude of men, ignoble in their race, took courage, and, pouring from the eaſt into Egypt, made war with the inhabitants; who ſubmitted to them without reſiſtance. The ſhepherds, however, behaved with the greateſt cruelty; burnt the cities, threw down the temples of the gods; and put to death the inhabitants, carrying the women and children into captivity. This people came from Arabia, and were called *Hycſos*, or *king-ſhepherds*. They held Egypt in ſubjection for 259 years; at the end of which period, they were obliged by a king of Upper Egypt, named *Amoſis*, or *Thethmoſis*, to leave the country. This prince's father had, it ſeems, gained great advantages over them, and ſhut them up in a place called *Abaris*, or *Avaris*, containing 10,000 acres of land. Here they were cloſely beſieged by Amoſis, with an army of 400,000 men; but at laſt the king, finding himſelf unable to reduce them by force, propoſed an agreement, which was readily accepted. In conſequence of this agreement, the ſhepherds withdrew from Egypt with their families, to the number of 240,000; and, taking the way of the deſert, entered Syria: but fearing the Aſſyrians, who were then very powerful, and maſters of Aſia, they entered the land of Judæa; and built there a city capable of holding ſo great a multitude, and called it *Jeruſalem*.

According to Mr Bruce, the ſhepherds who invaded Egypt were no other than the inhabitants of Barabra. They were, he ſays, *carriers* to the Cuſhites who lived farther to the ſouth. The latter had built the many ſtately temples in Thebes and other cities of Egypt; though, according to him, they had no dwelling places but holes or caves in the rocks. Being a commercial people, they remained at home collecting and preparing their articles, which were diſperſed by the *barabers* or ſhepherds already mentioned. Theſe, from the nature of their employment, lived in moveable habitations, as the Tartars do at this day. By the Hebrews, he tells us, they were called *phut*, but *ſhepherds* by every other people; and from the name *baraber*, the word *Barabra* is derived. By their employment, which was the diſperſing the Arabian and African goods all over the continent, they had become a great and powerful people; and from their oppoſite diſpoſitions and manners, became very frequently enemies to the Egyptians. To one Salatis our author aſcribes the deſtruction of Thebes in Upper Egypt, ſo much celebrated by Homer for its magnificence. But this certainly cannot be the caſe; for Homer wrote long after the time of Joſeph: and we find that even then the Egyptians had the ſhepherds in abhorrence, in all probability becauſe they had been grievouſly oppreſſed by them. Mr Bruce counts three invaſions of theſe people; the firſt that of Salatis already mentioned, who overthrew the firſt dynaſty of Egyptian kings from Menes, and deſtroyed Thebes: the ſecond was that of Sabacco or *So*; for according to him this was not the name of a ſingle prince, but of a people, and ſignifies *ſhepherds*: and the third, after the building of Memphis, where 240,000 of them were beſieged as above mentioned. But accounts of this kind are evidently inconſiſtent in the higheſt degree; for how is it poſſible that the *third* invaſion, antecedent to the building of Jeruſalem, could be poſterior to the *ſecond*, if the latter happened only in the days of Hezekiah?

In theſe early ages, however, it would ſeem that the kingdom of Egypt had been very powerful and its dominion very widely extended; ſince we find it ſaid, that the *Bactrians* revolted from Oſymandyas, another Egyptian king of very high antiquity, and of whoſe wealth the moſt marvellous accounts are given.

After an unknown interval of time from this monarch, reigned Seſoſtris. He was the firſt great warrior whoſe conqueſts are recorded with any degree of diſtinctneſs. In what age of the world he lived, is uncertain. Some chronologers, among whom is Sir Iſaac Newton, are of opinion, that he is the Seſac or Shiſhak, who took Jeruſalem in the reign of Rehoboam the ſon of Solomon. Others, however, place him much earlier; and Mr Whiſton will have him to be the Pharaoh who refuſed to part with the Iſraelites, and was at laſt drowned in the Red ſea. Mr Bryant endeavours to prove that no ſuch perſon ever exiſted; but that in his hiſtory as well as that of many ancient heroes, we have an abridgment of that of the Cuſhites or Babylonians, who ſpread themſelves over great part of the then known world, and everywhere brought the people in ſubjection to them. His reign is reckoned the moſt extraordinary part of the Egyptian hiſtory; and the following ſeems to be the leaſt fabulous account that can be got of it. The father of Seſoſtris was told in a dream, by the god Vulcan, that his ſon, who was then newly born, or perhaps ſtill unborn, ſhould be lord of the whole earth. His father, upon the credit of this viſion, got together all the males in the land of Egypt that were born on the ſame day with Seſoſtris; appointed nurſes and proper perſons to take care of them, and had them treated like his own child; being perſuaded that they who had been the conſtant companions of his youth would prove the moſt faithful miniſters and ſoldiers. As they grew up, they were inured to laborious exerciſes; and, in particular, were never permitted to taſte any food till they had performed a courſe of 180 furlongs, upwards of 22 of our miles. When the old king imagined they were ſufficiently educated in the martial way he deſigned them to follow, they were ſent by way of trial of their abilities againſt the Arabians. In this expedition Seſoſtris proved ſucceſsful, and in the end ſubdued that people who had never before been conquered. He was ſent to the weſtward, and conquered the greateſt part of Africa; nor could he be ſtopped in his career till he arrived at the Atlantic ocean. Whilſt he was on this expedition, his father died; and then Seſoſtris reſolved to fulfil the prediction of Vulcan, by actually conquering the whole world. As he knew that this muſt take up a long time, he prepared for his journey in the beſt manner poſſible. The kingdom he divided into 36 provinces, and endeavoured to ſecure the affections of the people by gifts both of money and land. He forgave all who had been guilty of offences, and diſcharged the debts of all his ſoldiers. He then conſtituted his brother Armais the ſupreme regent; but forbade him to uſe the diadem, and commanded him to offer no injury to the queen or her children, and to abſtain from the royal concubines. His army conſiſted of 600,000 foot, 24,000 horſe, and 27,000 chariots. Beſides theſe land forces, he had at ſea two mighty fleets; one, according to Diodorus, of 400 ſail. Of theſe fleets, one was deſigned to make conqueſts in the weſt, and the other in the eaſt; and therefore the one was built on the Mediterranean and the other on the Red ſea. The firſt of theſe conquered Cyprus, the coaſt of Phœnicia, and ſeveral of the iſlands called *Cyclades;* the other conquered all the coaſts of the Red ſea; but its progreſs was ſtopped by ſhoals and difficult places which the navigators could not paſs, ſo that he ſeems not to have made many conqueſts by ſea.

With the land forces Seſoſtris marched againſt the Ethiopians and Troglodites; whom he overcame, and obliged them to pay him a tribute of gold, ebony, and ivory. From thence he proceeded as far as the promontory of Dira, which lay near the ſtraits of Babelmandel, where he ſet up a pillar with an inſcription in ſacred characters. He then marched on to the country where cinnamon grows, or at leaſt to ſome country where cinnamon at that time was brought, probably ſome place in India; and here he in like manner ſet up pillars, which were to be ſeen for many ages after. As to his farther conqueſts, it is agreed by almoſt all authors of antiquity, that he overran and pillaged the whole continent of Aſia, and ſome part of Europe. He croſſed the Ganges, and erected pillars on its banks; and from thence he is ſaid to have marched eaſtward to the very extremity of the Aſiatic continent. Returning from thence, he invaded the Scythians and Thracians; but all authors do not agree that he conquered them. Some even affirm, that he was overthrown by them with great ſlaughter, and obliged to abandon a great part of his booty and military ſtores. But whether he had good or bad ſucceſs in theſe parts, it is a common opinion that he ſettled a colony in Colchis. Herodotus, however, who gives the moſt particular account of the conqueſts of this monarch, does not ſay whether the colony was deſignedly planted by Seſoſtris: or whether part of his army loitered behind the reſt, and took up their reſidence in that region. From his own knowledge, he aſſerts, that the inhabitants of that country were undoubtedly of Egyptian deſcent. This was evident from the perſonal reſemblance they bore to the Egyptians, who were ſwarthy complexioned and frizzle haired; but more eſpecially from the conformity of their cuſtoms, particularly circumciſion.

The utmoſt boundary of this mighty monarch's conqueſts, however, was in the country of Thrace; for beyond this country his pillars were nowhere to be ſeen. Theſe pillars he was accuſtomed to ſet up in every country which he conquered, with the following inſcription, or one to the ſame purpoſe: "Seſoſtris, kings of kings, and lord of lords, ſubdued this country by the power of his arms." Beſides theſe, he left alſo ſtatues of himſelf; two of which, according to Herodotus, were to be ſeen in his time; the one on the road between Epheſus and Phocæa, and the other between Smyrna and Sardis: they were armed after the Ethiopian and Egyptian manner; holding a javelin in one hand and a bow in the other. Acroſs the breaſt they had a line drawn from one ſhoulder to the other, with the following inſcription: "This region I obtained by theſe my ſhoulders." They were miſtaken for images of Memnon.

3 Returns to Egypt. The reaſons given by Seſoſtris for his returning into Egypt from Thrace, and thus leaving the conqueſt of the world unfiniſhed, were the want of proviſions for his army, and the difficulty of the paſſes. Moſt probably, however, his return was haſtened by the intelligence he received from the high prieſt of Egypt, concerning the rebellious proceedings of his brother; who, encouraged by his long abſence, had aſſumed the diadem, violated the queen, and alſo the royal concubines. On receiving this news, Seſoſtris haſtened from Thrace; and at the end of nine years came to Peluſium in Egypt, attended by an innumerable multitude of captives taken from many different nations, and loaded with the ſpoils of Aſia. The treacherous brother met him at this city; and it is ſaid, with very little probability, that Seſoſtris accepted of an invitation to an entertainment from him. At this he drank freely, together with the queen and the reſt of the royal family. During the continuance of the entertainment, Armais cauſed a great quantity of dried reeds to be laid round the apartment where they were to ſleep; and as ſoon as they were retired to reſt ſet fire to the reeds. Seſoſtris perceiving the danger he was in, and that his guards, overcharged with liquor, were incapable of aſſiſting him, ruſhed through the flames, and was followed by his wife and children. In thankſgiving for this wonderful deliverance, he made ſeveral donations to the gods, particularly to Vulcan the god of fire. He then took vengeance on his brother Armais, ſaid to be the Danaus of the Greeks, who, being on this occaſion driven out of Egypt, withdrew into Greece.

4 His great works. Seſoſtris now laid aſide all thoughts of war, and applied himſelf wholly to ſuch works as might tend to the public good, and his own future reputation. In order to prevent the incurſions of the Syrians and Arabians, he fortified the eaſt ſide of Egypt with a wall which ran from Peluſium through the deſert to Heliopolis, for 187½ miles. He raiſed alſo an incredible number of vaſt and lofty mounts of earth, to which he removed ſuch towns as had before been ſituated too low, in order to ſecure them from the inundations of the Nile. All the way from Memphis to the ſea he dug canals which branched out from the Nile; and not only made an eaſier communication between different places, but rendered the country in a great meaſure impaſſable to an enemy. He erected a temple in every city in Egypt, and dedicated it to the ſupreme deity of the place; but in the courſe of ſuch a great undertaking as this neceſſarily muſt have been, he took care not to employ any of his Egyptian ſubjects. Thus he ſecured their affection, and employed the vaſt multitude of captives he had brought along with him; and to perpetuate the memory of a tranſaction ſo remarkable, he cauſed to be inſcribed on all theſe temples, "No one native laboured hereon." In the city of Memphis, before the temple of Vulcan, he raiſed ſix gigantic ſtatues, each of one ſtone. Two of them were 30 cubits high, repreſenting himſelf and his wife; the other four were 20 cubits each, and repreſented his

four ſons. Theſe he dedicated to Vulcan in memory of his above-mentioned deliverance. He raiſed alſo two obeliſks of marble 120 cubits high, and charged them with inſcriptions, denoting the greatneſs of his power, his revenues, &c.

The captives taken by Seſoſtris are ſaid to have been treated with the greateſt barbarity; ſo that at laſt they reſolved at all events to deliver themſelves from a ſervitude ſo intolerable. The Babylonians particularly were concerned in this revolt, and laid waſte the country to ſome extent; but being offered a pardon and a place to dwell in, they were pacified, and built for themſelves a city, which they called *Babylon*. Towards the conquered princes who waited on him with their tribute the Egyptian monarch behaved with unparalleled inſolence. On certain occaſions he is ſaid to have unharnaſſed his horſes, and, yoking kings together, made them draw his chariot. One day, however, obſerving one of the kings who drew his chariot to look back upon the wheels with great earneſtneſs, he aſked what made him look ſo attentively at them? The unhappy prince replied, "O king, the going round of the wheel puts me in mind of the viciſſitudes of fortune: for as every part of the wheel is uppermoſt and lowermoſt by turns, ſo it is with men; who one day ſit on a throne, and on the next are reduced to the vileſt degree of ſlavery." This anſwer brought the inſulting conqueror to his ſenſes; ſo that he gave over the practice, and thenceforth treated his captives with great humanity. At length this mighty monarch loſt his ſight, and laid violent hands on himſelf.

5
His death.

After the death of Seſoſtris, we meet with another chaſm of an indeterminate length in the Egyptian hiſtory. It concludes with the reign of Amaſis or Ammoſis; who being a tyrant, his ſubjects joined Actiſanes the king of Ethiopia to drive him out.—Thus Actiſanes became maſter of the kingdom; and after his death follows another chaſm in the hiſtory, during which the empire is ſaid to have been in a ſtate of anarchy for five generations.—This period brings us down to the times of the Trojan war. The reigning prince in Egypt was at that time called *Cetes;* by the Greeks, *Proteus*. The prieſts reported that he was a magician; and that he could aſſume any ſhape he pleaſed, even that of fire. This fable, as told by the Greeks, drew its origin from a cuſtom among the Egyptians, perhaps introduced by Proteus. They were uſed to adorn and diſtinguiſh the heads of their kings with the repreſentations of animals or vegetables, or even with burning incenſe, in order to ſtrike the beholders with the greater awe. Whilſt Proteus reigned, Paris or Alexander, the ſon of Priam king of Troy, was driven by a ſtorm on the coaſt of Egypt, with Helen, whom he was carrying off from her huſband. But when the Egyptian monarch heard of the breach of hoſpitality committed by Paris, he ſeized him, his miſtreſs, and companions, with all the riches he had brought away with him from Greece. He detained Helen, with all the effects belonging to Menelaus her huſband, promiſing to reſtore them to the injured party whenever they were demanded; but commanded Paris and his companions to depart out of his dominions in three days, on pain of being treated as enemies. In what manner Paris afterwards prevailed upon Proteus to reſtore his miſtreſs, we are not told; neither do we know any thing further of the tranſactions of this prince's reign nor of his ſucceſſors, except what has entirely the air of fable, till the days of Sabbaco the Ethiopian, who again conquered this kingdom. He began his reign with an act of great cruelty, cauſing the conquered prince to be burnt alive: nevertheleſs, he no ſooner ſaw himſelf firmly eſtabliſhed on the throne of Egypt, than he became a new man; ſo that he is highly extolled for his mercy, clemency, and wiſdom. He is thought to have been the *So* mentioned in Scripture, and who entered into a league with Hoſhea king of Iſrael againſt Shalmaneſer king of Aſſyria. He is ſaid to have been excited to the invaſion of Egypt by a dream or viſion, in which he was aſſured that he ſhould hold that kingdom for 50 years. Accordingly, he conquered Egypt, as had been foretold; and at the expiration of the time above mentioned, he had another dream, in which the tutelar god of Thebes acquainted him, that he could no longer hold the kingdom of Egypt with ſafety and happineſs, unleſs he maſſacred the prieſts as he paſſed through them with his guards. Being haunted with this viſion, and at the ſame time abhorring to hold the kingdom on ſuch terms, he ſent for the prieſts, and acquainted them with what ſeemed to be the will of the gods. Upon this it was concluded, that it was the pleaſure of the Deity that Sabbaco ſhould remain no longer in Egypt; and therefore he immediately quitted that kingdom, and returned to Ethiopia.

6
Origin of the fable of Proteus.

7
Arrival of Paris and Helen in Egypt.

8
Egypt conquered by Sabbaco.

Of *Anyſias*, who was Sabbaco's immediate ſucceſſor, we have no particulars worth notice. After him reigned one Sethon, who was both king and prieſt of Vulcan. He gave himſelf up to religious contemplation; and not only neglected the military claſs, but deprived them of their lands. At this they were ſo much incenſed, that they entered into an agreement not to bear arms under him; and in this ſtate of affairs Sennacherib king of Aſſyria arrived before Peluſium with a mighty army. Sethon now applied to his ſoldiers, but in vain: they unanimouſly perſiſted in refuſing to march under his banner. Being therefore deſtitute of all human aid, he applied to the god Vulcan, and requeſted him to deliver him from his enemies. Whilſt he was yet in the temple of that god, it is ſaid he fell into a deep ſleep; during which he ſaw Vulcan ſtanding at his ſide, and exhorting him to take courage. He promiſed, that if Sethon would but go out againſt the Aſſyrians, he ſhould obtain a complete victory over them. Encouraged by this aſſurance, the king aſſembled a body of artificers, ſhop-keepers, and labourers; and, with this undiſciplined rabble, marched towards Peluſium. He had no occaſion, however, to fight; for the very night after his arrival at Peluſium, an innumerable multitude of field rats entering the enemies camp, gnawed to pieces the quivers, bowſtrings, and ſhield ſtraps. Next morning, when Sethon found the enemy diſarmed, and on that account beginning to fly, he purſued them to a great diſtance, making a terrible ſlaughter. In memory of this extraordinary event, a ſtatue of Sethon was erected in the temple of Vulcan, holding in one hand a rat, and delivering theſe words; "Whoſoever beholdeth me let him be pious."

9
Remarkable ſtory of Sethon.

Soon after the death of Sethon, the form of government in Egypt was totally changed. The kingdom was divided into twelve parts, over which as many of

10
Reign of Pſammitichus.

the chief nobility preſided. This diviſion, however, ſubſiſted but for a ſhort time. Pſammitichus, one of the twelve, dethroned all the reſt, 15 years after the diviſion had been made. The hiſtory now begins to be diveſted of fable; and from this time may be accounted equally certain with that of any other nation. The vaſt conqueſts of Seſoſtris were now no longer known; for Pſammitichus poſſeſſed no more than the country of Egypt itſelf. It appears, indeed, that none of the ſucceſſors of Seſoſtris, or even that monarch himſelf, had made uſe of any means to keep in ſubjection the countries he had once conquered. Perhaps, indeed, his deſign originally was rather to *pillage* than to conquer; and therefore, on his return, his vaſt empire vaniſhed at once. Pſammitichus, however, endeavoured to extend his dominions by making war on his neighbours; but by putting more confidence in foreign auxiliaries than in his own ſubjects, the latter were ſo much offended, that upwards of 200,000 fighting men emigrated in a body, and took up their reſidence in Ethiopia. To repair this loſs, Pſammitichus earneſtly applied himſelf to the advancement of commerce; and opened his port to all ſtrangers, whom he greatly careſſed, contrary to the cruel maxims of his predeceſſoas, who refuſed to admit them into the country. He alſo laid ſiege to the city of Azotus in Syria, which held out for 29 years againſt the whole ſtrength of the kingdom; from which we may gather, that, as a warrior, Pſammitichus was by no means remarkable. He is reported to have been the firſt king of Egypt that drank wine. He alſo ſent to diſcover the ſprings of the Nile; and is ſaid to have attempted to diſcover the moſt ancient nation in the world by the following method. Having procured two newly born children, he cauſed them to be brought up in ſuch a manner that they never heard a human voice. He imagined that theſe children would naturally ſpeak the original language of mankind: therefore, when, at two years of age, they pronounced the Phrygian word *becos* (or ſome ſound reſembling it), which ſignifies bread, he concluded that the Phrygians were the moſt ancient people in the world.

11
Succeeded by Nechus.

Nechus, the ſon and ſucceſſor of Pſammitichus, is the *Pharaoh-Necho* of Scripture, and was a prince of an enterpriſing and warlike genius. In the beginning of his reign, he attempted to cut through the iſthmus of Suez, between the Red ſea and the Mediterranean; but, through the invincible obſtacles which nature has thrown in the way of ſuch undertakings, he was obliged to abandon the enterpriſe, after having loſt 120,000 men in the attempt. After this he ſent a ſhip, manned with ſome expert Phœnician mariners, on a voyage to explore the coaſts of Africa. Accordingly, they performed the voyage; ſailed round the continent of Africa; and after three years returned to Egypt, where their relation was deemed incredible.

12
His wars with Joſiah and Nebuchadnezzar.

The moſt remarkable wars in which this king was engaged are recorded in the ſacred writings. He went out againſt the king of Aſſyria, by the divine command, as he himſelf told Joſiah; but being oppoſed by the king of Judea, he defeated and killed him at Megiddo; after which he ſet up, in that country, King Jehoiakim, and impoſed on him an annual tribute of 100 talents of ſilver and one talent of gold. He then proceeded againſt the king of Aſſyria; and weakened him ſo much, that the empire was ſoon after diſſolved. Thus he became maſter of Syria and Phœnicia; but in a ſhort time, Nebuchadnezzar king of Babylon came againſt him with a mighty army. The Egyptian monarch, not daunted by the formidable appearance of his antagoniſt, boldly ventured a battle; but was overthrown with prodigious ſlaughter, and Nebuchadnezzar became maſter of all the country to the very gates of Peluſium.

13
Apries a martial and ſucceſsful prince.

The reign of Apries, the *Pharaoh-Hophra* of Scripture, preſents us with a new revolution in the Egyptian affairs. He is repreſented as a martial prince, and in the beginning of his reign very ſucceſsful. He took by ſtorm the rich city of Sidon; and having overcome the Cypriots and Phœnicians in a ſea fight, returned to Egypt laden with ſpoil. This ſucceſs probably incited Zedekiah king of Judæa to enter into an alliance with him againſt Nebuchadnezzar king of Babylon. The bad ſucceſs of this alliance was foretold by the prophet Jeremiah; and accordingly it happened. For Nebuchadnezzar having ſat down with his army before Jeruſalem, Apries marched from Egypt with a deſign to relieve the city; but no ſooner did he perceive the Babylonians approaching him, than he retreated as faſt as he could, leaving the Jews expoſed to the rage of their mercileſs enemies; who were thereupon treated as Jeremiah had foretold; and by this ſtep Apries brought upon himſelf the vengeance denounced by the ſame prophet. The manner in which theſe predictions were fulfilled is as follows: The Cyreneans, a colony of the Greeks, being greatly ſtrengthened by a numerous ſupply of their countrymen under their third king *Battus* ſtyled *the Happy*, and encouraged by the Pythian oracle, began to drive out their Libyan neighbours, and ſhared their poſſeſſions among themſelves. Hereupon Andica king of Libya ſent a ſubmiſſive embaſſy to Apries, and implored his protection againſt the Cyreneans. Apries complied with his requeſt, and ſent a powerful army to his relief. The Egyptians were defeated with great ſlaughter; and thoſe who returned complained that the army had been ſent off by Apries in order to be deſtroyed, and that he might tyrannize without controul over the remainder of his ſubjects. This thought catching the attention of the giddy multitude, an almoſt univerſal defection enſued. Apries ſent one Amaſis, a particular friend, in whom he thought he could confide, to bring back his people to a ſenſe of their duty. But by this friend he was betrayed; for Amaſis, taking the opportunity of the preſent ferment, cauſed himſelf to be proclaimed king. Apries then deſpatched one Patarbemis, with orders to take Amaſis, and bring him alive before him. This he found impoſſible, and therefore returned without his priſoner; at which the king was ſo enraged, that he commanded Patarbemis's noſe and ears to be cut off. This piece of cruelty completed his ruin; for when the reſt of the Egyptians who continued faithful to Apries beheld the inhuman mutilation of ſo worthy and noble a perſon as Patarbemis was, they to a man deſerted Apries, and went over to Amaſis.

14
Bad conſequences of his alliance with Zedekiah.

15
His ſubjects revolt.

Both parties now prepared for war; the uſurper having under his command the whole body of native Egyptians; and Apries only thoſe Ionians, Carians, and other mercenaries whom he could engage in his ſervice.

16 Apries defeated and taken priſoner by Amaſis.

vice. The army of Apries amounted only to 30,000; but, though greatly inferior in number to the troops of his rival, as he well knew that the Greeks were much ſuperior in valour, he did not doubt of victory. Nay, ſo far was Apries puffed up with this notion, that he did not believe it was in the power even of any *god* to deprive him of his kingdom. The two armies ſoon met, and drew up in order of battle near Memphis. A bloody engagement enſued; in which, though the army of Apries behaved with the greateſt reſolution, they were at laſt overpowered with numbers, and utterly defeated, the king himſelf being taken priſoner. Amaſis now took poſſeſſion of the throne without oppoſition. He confined Apries in one of his palaces, but treated him with great care and reſpect. The people, however, were implacable, and could not be ſatisfied while he enjoyed his life. Amaſis, therefore, at laſt found himſelf obliged to deliver him into their hands. Thus the prediction received its final completion: Apries was delivered up to thoſe *who ſought his life;* and who no ſooner had him in their power, than they ſtrangled him, and laid his body in the ſepulchre of his anceſtors.

17 Egypt invaded by Nebuchadnezzar.

During theſe inteſtine broils, which muſt have greatly weakened the kingdom, it is probable that Nebuchadnezzar invaded Egypt. He had been for 13 years before this employed in beſieging Tyre, and at laſt had nothing but an empty city for his pains. To make himſelf ſome amends, therefore, he entered Egypt, miſerably haraſſed the country, killed and carried away great numbers of the inhabitants, ſo that the country did not recover from the effects of this incurſion for a long time after. In this expedition, however, he ſeems not to have aimed at any permanent conqueſt, but to have been induced to it merely by the love of plunder, and of this he carried with him an immenſe quantity to Babylon.

18 Happy adminiſtration of Amaſis.

During the reign of Amaſis, Egypt is ſaid to have been perfectly happy, and to have contained 20,000 populous cities. That good order might be kept among ſuch vaſt numbers of people, Amaſis enacted a law, by which every Egyptian was bound once a-year to inform the governor of his province by what means he gained his livelihood; and if he failed of this, to put him to death. The ſame puniſhment he decreed to thoſe who could not give a ſatisfactory account of themſelves.

This monarch was a great favourer of the Greeks, and married a woman of Grecian extract. To many Greek cities, as well as particular perſons, he made conſiderable preſents. Beſides theſe, he gave leave to the Greeks in general to come into Egypt, and ſettle either in the city of Naucratis, or carry on their trade upon the ſea coaſts; granting them alſo temples, and places where they might erect temples to their own deities. He received alſo a viſit from Solon the celebrated Athenian lawgiver, and reduced the iſland of Cyprus under his ſubjection.

19 Offends Cambyſes king of Perſia.

This great proſperity, however, ended with the death of Amaſis, or indeed before it. The Egyptian monarch had ſome how or other incenſed Cambyſes king of Perſia. The cauſe of the quarrel is uncertain; but whatever it was, the Perſian monarch vowed the deſtruction of Amaſis. In the mean time *Phanes* of Halicarnaſſus, commander of the Grecian auxiliaries in the pay of Amaſis, took ſome private diſguſt; and leaving Egypt, embarked for Perſia. He was a wiſe and able general, perfectly well acquainted with every thing that related to Egypt; and had great credit with the Greeks in that country. Amaſis was immediately ſenſible how great the loſs of this man would be to him, and therefore ſent after him a truſty eunuch with a ſwift galley. Phanes was accordingly overtaken in Lycia, but not brought back; for making his guard drunk, he continued his journey to Perſia, and preſented himſelf before Cambyſes, as he was meditating the deſtruction of the Egyptian monarchy.

20 And Polycrates tyrant of Samos.

At this dangerous criſis alſo, the Egyptian monarch imprudently made Polycrates the tyrant of Samos his enemy. This man had been the moſt remarkable perhaps of any recorded in hiſtory, for an uninterrupted courſe of ſucceſs, without the intervention of one ſingle unfortunate event. Amaſis, who was at this time in ſtrict alliance with Polycrates, wrote him a letter, in which, after congratulating him on his proſperity, he told him that he was afraid leſt his ſucceſſes were too many, and he might be ſuddenly thrown down into the greateſt miſery. For this reaſon he adviſed him voluntarily to take away ſomething from his own happineſs; and to caſt away that which would grieve him moſt if he was accidentally to loſe it. Polycrates followed his advice, and threw into the ſea a ſignet of ineſtimable value. This, however, did not anſwer the intended purpoſe. The ſignet happened to be ſwallowed by a fiſh, which was taken a few days afterwards, and thus was reſtored to Polycrates. Of this Amaſis was no ſooner informed, than, conſidering Polycrates as really *unhappy*, and already on the brink of deſtruction, he reſolved to put an end to the friendſhip which ſubſiſted between them. For this purpoſe he deſpatched a herald to Samos, commanding him to acquaint Polycrates, that he renounced his alliance, and all the obligations between them; that he might not mourn his misfortunes with the ſorrow of a friend. Thus Amaſis left Polycrates at liberty to act againſt him, if he choſe to do ſo; and accordingly he offered to aſſiſt Cambyſes with a fleet of ſhips in his Egyptian expedition.

21 Egypt invaded by Cambyſes.

Amaſis had not, however, the misfortune to ſee the calamities of his country. He died about 525 years before Chriſt, after a reign of 44 years; and left the kingdom to his ſon Pſammenitus, juſt as Cambyſes was approaching the frontiers of the kingdom. The new prince was ſcarce ſeated on the throne, when the Perſians appeared. Pſammenitus drew together what forces he could, in order to prevent them from entering the kingdom. Cambyſes, however, immediately laid ſiege to Peluſium, and made himſelf maſter of it by the following ſtratagem: he placed in the front of his army a great number of cats, dogs, and other animals that were deemed ſacred by the Egyptians. He then attacked the city, and took it without oppoſition; the garriſon, which conſiſted entirely of Egyptians, not daring to throw a dart or ſhoot an arrow againſt their enemies, leſt they ſhould kill ſome of the holy animals.

22 Cruelty and defeat of the Egyptians.

Cambyſes had ſcarce taken poſſeſſion of the city, when Pſammenitus advanced againſt him with a numerous army. But before the engagement, the Greeks who ſerved under Pſammenitus, to ſhow their indignation againſt their treacherous countryman Phanes, brought his children into the camp, killed them in the preſence of their father and of the two armies, and then drank their blood. The Perſians enraged at ſo cruel a ſight, fell upon the Egyptians with the utmoſt fury, put them to flight, and cut the greateſt part of them in pieces. Thoſe who eſcaped fled to Memphis, where they were ſoon after guilty of a horrid outrage. Cambyſes ſent a herald to them in a ſhip from Mitylene: but no ſooner did they ſee her come into the port, than they flocked down to the ſhore, deſtroyed the ſhip, and tore to pieces the herald and all the crew, afterwards carrying their mangled limbs into the city, in a kind of barbarous triumph. Not long after, they were obliged to ſurrender: and thus Pſammenitus fell into the hands of his inveterate enemy, who was now enraged beyond meaſure at the cruelties exerciſed upon the children of Phanes, the herald, and the Mitylenean ſailors.

23
Their dreadful puniſhment by Cambyſes.

The rapid ſucceſs of the Perſians ſtruck with ſuch terror the Libyans, Cyreneans, Barcæans, and other dependents or allies of the Egyptian monarch, that they immediately ſubmitted. Nothing now remained but to diſpoſe of the captive king, and revenge on him and his ſubjects the cruelties which they had committed. This the mercileſs victor executed in the ſevereſt manner. On the 10th day after Memphis had been taken, Pſammenitus and the chief of the Egyptian nobility were ignominiouſly ſent into one of the ſuburbs of that city. The king being there ſeated in a proper place, ſaw his daughter coming along in the habit of a poor ſlave with a pitcher to fetch water from the river, and followed by the daughters of the greateſt families in Egypt, all in the ſame miſerable garb, with pitchers in their hands, drowned in tears, and loudly bemoaning their miſerable ſituation. When the fathers ſaw their daughters in this diſtreſs, they burſt into tears, all but Pſammenitus, who only caſt his eyes on the ground and kept them fixed there. After the young women, came the ſon of Pſammenitus, with 2000 of the young nobility, all of them with bits in their mouths and halters round their necks, led to execution. This was done to expiate the murder of the Perſian herald and the Mitylenean ſailors; for Cambyſes cauſed ten Egyptians of the firſt rank to be publicly executed for every one of thoſe that had been ſlain. Pſammenitus, however, obſerved the ſame conduct as before, keeping his eyes ſtedfaſtly fixed on the ground, though all the Egyptians around him made the loudeſt lamentations. A little after this he ſaw an intimate friend and companion, now advanced in years, who having been plundered of all he had, was begging his bread from door to door in the ſuburbs. As ſoon as he ſaw this man, Pſammenitus wept bitterly; and calling out to him by his name, ſtruck himſelf on the head as if he had been frantic. Of this the ſpies who had been ſet over him to obſerve his behaviour, gave immediate notice to Cambyſes, who thereupon ſent a meſſenger to inquire the cauſe of ſuch immoderate grief. Pſammenitus anſwered, That the calamities of his own family confounded him, and were too great to be lamented by any outwards ſigns of grief; but the extreme diſtreſs of a boſom friend gave more room for reflection, and therefore extorted tears from him. With this anſwer Cambyſes was ſo affected, that he ſent orders to prevent the execution of the king's ſon; but theſe came too late, for the young prince had been put to death before any of the reſt. Pſammenitus himſelf was then ſent for into the city, and reſtored to his liberty: and had he not ſhowed a deſire of revenge, might perhaps have been truſted with the government of Egypt: but being diſcovered hatching ſchemes againſt the government, he was ſeized, and condemned to drink bull's blood.

24
Egypt becomes a province of the Perſian, and afterwards of the Grecian empire.

The Egyptians were now reduced to the loweſt degree of ſlavery. Their country became a province of the Perſian empire: the body of Amaſis their late king was taken out of his grave; and after being mangled in a ſhocking manner was finally burnt. But what ſeemed more grievous than all the reſt, their god Apis was ſlain, and his prieſts ignominiouſly ſcourged; and this inſpired the whole nation with ſuch a hatred to the Perſians, that they could never afterwards be reconciled to them. As long as the Perſian empire ſubſiſted, the Egyptians could never ſhake off their yoke. They frequently revolted indeed, but were always overthrown with prodigious loſs. At laſt they ſubmitted, without oppoſition, to Alexander the Great: after his death, Egypt again became a powerful kingdom; though ſince the conqueſt of it by Cambyſes to the preſent time it hath never been governed but by foreign princes, agreeable to the prophecy of Ezekiel. "There ſhall be no more a prince of the land of Egypt."

25
Aſſigned to Ptolemy Lagus, who aſſumes the title of king.

On the death of Alexander the Great, Egypt, together with Libya, and that part of Arabia which borders on Egypt, were aſſigned to Ptolemy Lagus as governor under Alexander's ſon by Roxana, who was but newly born. Nothing was farther from the intention of this governor, than to keep the provinces in truſt for another. He did not, however, aſſume the title of *king*, till he perceived his authority ſo firmly eſtabliſhed that it could not be ſhaken; and this did not happen till 19 years after the death of Alexander, when Antigonus and Demetrius had unſucceſsfully attempted the conqueſt of Egypt.

From the time of his firſt eſtabliſhment on the throne, Ptolemy, who had aſſumed the title of *Soter*, reigned 20 years; which added to the former 19, make up the 39 years which hiſtorians commonly allow him to have reigned alone.—In the 39th year of his reign, he made one of his ſons, named *Philadelphus*, partner to the empire; declaring him his ſucceſſor, to the prejudice of his eldeſt ſon named *Ceraunus;* being excited thereto by his violent love for *Berenice* Philadelphus's mother. When the ſucceſſion was thus ſettled, Ceraunus immediately quitted the court; and fled at laſt into Syria, where he was received with open arms by Seleucus Nicator, whom he afterwards murdered.

The moſt remarkable tranſaction of this reign was the embelliſhing of the city of Alexandria, which Ptolemy made the capital of his new kingdom, and of which an account is given under the article ALEXANDRIA. About 284 years before Chriſt, died Ptolemy Soter, in the 41ſt year of his reign, and 84th of his age. He was the beſt prince of his race; and left behind him an example of prudence, juſtice, and clemency which few of his ſucceſſors choſe to follow. Beſides the provinces originally aſſigned to him, he added to his empire thoſe of Cœlo-Syria, Ethiopia, Pamphylia, Lycia,

26
Succeeded by Philadelphus.

Lycia, Caria, and ſome of the Cyclades. His ſucceſſor, Ptolemy Philadelphus, added nothing to the extent of the empire; nor did he perform any thing worthy of notice except embelliſhing further the city of Alexandria, and entering into an alliance with the Romans. In his time, one Magas, the governor of Libya and Cyrene, revolted: and held theſe provinces as an independent prince, notwithſtanding the utmoſt efforts of Ptolemy to reduce him. At laſt an accommodation took place; and a marriage was propoſed between Berenice, the only daughter of Magas, and Ptolemy's eldeſt ſon. The young princeſs was to receive all her father's dominions by way of dowry, and thus they would again be brought under the dominion of Ptolemy's family. But before this treaty could be put in execution, Magas died; and then Apamea, the princeſs's mother, did all ſhe could to prevent the match. This, however, ſhe was not able to do; though her efforts for that purpoſe produced a deſtructive war of four years continuance with Antiochus Theus king of Syria, and the acting of a cruel tragedy in the family of the latter. See SYRIA.

27
Ptolemy Euergetes a great conqueror.

About 246 years before Chriſt, Ptolemy Philadelphus died; and was ſucceeded by his eldeſt ſon Ptolemy, who had been married to Berenice the daughter of Magas as above related. In the beginning of his reign, he found himſelf engaged in a war with Antiochus Theus king of Syria. From this he returned victorious, and brought with him 2500 ſtatues and pictures, among which were many of the ancient Egyptian idols, which had been carried away by Cambyſes into Perſia. Theſe were reſtored by Ptolemy to their ancient temples; in memory of which favour, the Egyptians gave him the ſurname of *Euergetes*, or the Beneficent. In this expedition he greatly enlarged his dominions, making himſelf maſter of all the countries that lie between Mount Taurus and the confines of India. An account of theſe conqueſts was given by himſelf, inſcribed on a monument, to the following effect. "Ptolemy Euergetes, having received from his father the ſovereignty of Egypt, Libya, Syria, Phœnice, Cyprus, Lycia, Caria, and the other Cyclades, aſſembled a mighty army of horſe and foot, with a great fleet, and elephants, out of Trogloditia and Ethiopia; ſome of which had been taken by his father, and the reſt by himſelf, and brought from thence, and trained up for war: with this great force he ſailed into Aſia; and having conquered all the provinces which lie on this ſide the Euphrates, Cilicia, Pamphylia, Ionia, the Helleſpont, and Thrace, he croſſed that river with all the forces of the conquered countries, and the kings of thoſe nations, and reduced Meſopotamia, Babylonia, Suſiana, Perſia, Media, and all the country as far as Bactria."

On the king's return from this expedition, he paſſed through Jeruſalem, where he offered many ſacrifices to the God of Iſrael, and ever afterwards expreſſed a great favour for the Jewiſh nation. At this time, the Jews were tributaries to the Egyptian monarchs, and paid them annually 20 talents of ſilver. This tribute, however, Onias, who was then high prieſt, being of a very covetous diſpoſition, had for a long time neglected to pay, ſo that the arrears amounted to a very large ſum. Soon after his return, therefore, Ptolemy ſent one of his courtiers named *Athenion* to demand the money, and deſired him to acquaint the Jews that he would make war upon them in caſe of a refuſal. A young man, however, named *Joſeph*, nephew to Onias, not only found means to avert the king's anger, but even got himſelf choſen his receiver general, and by his faithful diſcharge of that important truſt, continued in high favour with Ptolemy as long as he lived.

28
Cleomenes king of Sparta takes refuge in Egypt.

Ptolemy Euergetes having at laſt concluded a peace with Seleucus the ſucceſſor of Antiochus Theus king of Syria, attempted the enlargement of his dominions on the ſouth ſide. In this he was attended with ſuch ſucceſs, that he made himſelf maſter of all the coaſts of the Red ſea, both on the Arabian and Ethiopian ſides, quite down to the ſtraits of Babelmandel. On his return he was met by ambaſſadors from the Achæans, imploring his aſſiſtance againſt the Etolians and Lacedemonians. This the king readily promiſed them; but they having in the mean time engaged Antigonus king of Macedon to ſupport them, Ptolemy was ſo much offended, that he ſent powerful ſuccours to Cleomenes king of Sparta; hoping, by that means, to humble both the Achæans and their new ally Antigonus. In this, however, he was diſappointed; for Cleomenes, after having gained very conſiderable advantages over the enemy, was at laſt entirely defeated in the battle of Sellaſia, and obliged to take refuge in Ptolemy's dominions. He was received by the Egyptian monarch with the greateſt demonſtrations of kindneſs; a yearly penſion of 24 talents was aſſigned him, with a promiſe of reſtoring him to the Spartan throne; but before this could be accompliſhed, the king of Egypt died, in the 27th year of his reign, and was ſucceeded by his ſon Ptolemy Philopater.

29
Ptolemy Philopater a cruel tyrant.

Thus we have ſeen the Egyptian empire brought to a very great height of power; and had the ſucceeding monarchs been careful to preſerve that ſtrength of empire tranſmitted to them by Euergetes, it is very probable that Egypt might have been capable of holding the balance againſt Rome, and after the deſtruction of Carthage prevented that haughty city from becoming miſtreſs of the world. But after the death of Ptolemy Euergetes, the Egyptian empire, being governed only by weak or vicious monarchs, quickly declined, and from that time makes no conſpicuous figure in hiſtory. Ptolemy Philopater began his reign with the murder of his brother; after which, giving himſelf up to all manner of licentiouſneſs, the kingdom fell into a kind of anarchy. Cleomenes the Spartan king ſtill reſided at court; and being now unable to bear the diſſolute manners which prevailed there, he preſſed Philopater to give him the aſſiſtance he had promiſed for reſtoring him to the throne of Sparta. This he the rather inſiſted upon, becauſe he had received advice that Antigonus king of Macedon was dead, that the Achæans were engaged in a war with the Etolians, and that the Lacedemonians had joined the latter againſt the Achæans and Macedonians. Ptolemy, when afraid of his brother Magas, had indeed promiſed to aſſiſt the king of Sparta with a powerful fleet, hoping by this means to attach him to his own intereſt; but now when Magas was out of the way, it was determined by the king, or rather his miniſters, that Cleomenes ſhould not be aſſiſted, nor even allowed to leave the kingdom; and this extravagant reſolution produced the deſperate attempt of Cleomenes, of which an account is given in the hiſtory of SPARTA.

Of the diſorders which now enſued in the government, Antiochus king of Syria, ſurnamed *the Great*, took the advantage, and attempted to wreſt from Ptolemy the provinces of Cœlo-Syria and Paleſtine. But in this he was finally diſappointed; and might eaſily have been totally driven out of Syria, had not Ptolemy been too much taken up with his debaucheries to think of carrying on the war. The diſcontent occaſioned by this piece of negligence ſoon produced a civil war in his dominions, and the whole kingdom continued in the utmoſt confuſion till his death, which happened in the 17th year of his reign and 37th of his age.

30
Extraordinary ſtory concerning the Jews.

During the reign of Philopater happened a very extraordinary event with regard to the Jews, which is mentioned in the Maccabees *. The king of Egypt, while on his Syrian expedition, had attempted to enter the temple of Jeruſalem; but being hindered by the Jews, he was filled with the utmoſt rage againſt the whole nation. On his return to Alexandria, he reſolved to make thoſe who dwelt in that city feel the firſt effects of his vengeance. He began with publiſhing a decree, which he cauſed to be engraved on a pillar erected for that purpoſe at the gate of his palace, excluding all thoſe who did not ſacrifice to the gods worſhipped by the king. By this means the Jews were debarred from ſuing to him for juſtice, or obtaining his protection when they happened to ſtand in need of it. By the favour of Alexander the Great, Ptolemy Soter, and Euergetes, the Jews enjoyed at Alexandria the ſame privileges with the Macedonians. In that metropolis the inhabitants were divided into three ranks or claſſes. In the firſt were the Macedonians, or original founders of the city, and along with them were enrolled the Jews; in the ſecond were the mercenaries who had ſerved under Alexander; and in the third the native Egyptians. Ptolemy now, to be revenged of the Jews, ordered, by another decree, that they ſhould be degraded from the firſt rank, and enrolled among the native Egyptians. By the ſame decree it was enacted, that all of that nation ſhould appear at an appointed time before the proper officers, in order to be enrolled among the common people; that at the time of their enrollment they ſhould have the mark of an ivy leaf, the badge of Bacchus, impreſſed with a hot iron on their faces; that all who were thus marked ſhould be made ſlaves; and, laſtly, that if any one ſhould ſtand out againſt this decree, he ſhould be immediately put to death. That he might not, however, ſeem an enemy to the whole nation, he declared, that thoſe who ſacrificed to their gods ſhould enjoy their former privileges, and remain in the ſame claſs. Yet, notwithſtanding this tempting offer, 300 only out of many thouſand Jews who lived in Alexandria could be prevailed upon to abandon their religion in order to ſave themſelves from ſlavery.

The apoſtates were immediately excommunicated by their brethren: and this their enemies conſtrued as done in oppoſition to the king's order; which threw the tyrant into ſuch a rage, that he reſolved to extirpate the whole nation, beginning with the Jews who lived in Alexandria and other cities of Egypt, and proceeding from thence to Judæa and Jeruſalem itſelf. In conſequence of this cruel reſolution, he commanded all the Jews that lived in any part of Egypt to be brought in chains to Alexandria, and there to be ſhut up in the Hippodrome, which was a very ſpacious place without the city, where the people uſed to aſſemble to ſee horſe races and other public diverſions. He then ſent for Herman maſter of the elephants; and commanded him to have 500 of theſe animals ready againſt the next day, to let looſe upon the Jews in the Hippodrome. But when the elephants were prepared for the execution, and the people were aſſembled in great crowds to ſee it, they were for that day diſappointed by the king's abſence. For, having been late up the night before with ſome of his debauched companions, he did not awake till the time for the ſhow was over, and the ſpectators returned home. He therefore ordered one of his ſervants to call him early on the following day, that the people might not meet with a ſecond diſappointment. But when the perſon awaked him according to his order, the king was not yet returned to his ſenſes; having withdrawn, exceedingly drunk, only a ſhort time before. As he did not remember the order, he therefore fell into a violent paſſion, and threatened with death the ſervant who had awaked him; and this cauſed the ſhow to be put off till the third day. At laſt the king came to the Hippodrome attended with a vaſt multitude of ſpectators; but when the elephants were let looſe, inſtead of falling upon the Jews, they turned their rage againſt the ſpectators and ſoldiers, and deſtroyed great numbers of them. At the ſame time, ſome frightful appearances which were ſeen in the air ſo terrified the king, that he commanded the Jews to be immediately ſet at liberty, and reſtored them to their former privileges. No ſooner were they delivered from this danger than they demanded leave to put to death ſuch of their nation as had abandoned their religion; and this being granted, they deſpatched the apoſtates without excepting a ſingle man.

31
Ptolemy Philometor taken priſoner by Antiochus, and Phyſcon raiſed to the throne.

Philopater was ſucceeded by Ptolemy Epiphanes; and he, after a reign of 24 years, by Ptolemy Philometor. In the beginning of his reign, a war commenced with the king of Syria, who had ſeized on the provinces of Cœlo-Syria and Paleſtine in the preceding reign. In the courſe of this war, Philometer was either voluntarily delivered up to Antiochus or taken priſoner. But however this was, the Alexandrians deſpairing of his ever being able to recover his liberty, raiſed to the throne his brother Ptolemy, who took the name of *Euergetes II.* but was afterwards called *Phyſcon* or "the great-bellied," on account of the prominent belly which by his gluttony and luxury he had acquired. He was ſcarce ſeated on the throne, however, when Antiochus Epiphanes, returning into Egypt, drove out Phyſcon, and reſtored the whole kingdom except Peluſium, to Philometor. His deſign was to kindle a war betwixt the two brothers, ſo that he might have an opportunity of ſeizing the kingdom for himſelf. For this reaſon he kept to himſelf the city of Peluſium; which being the key of Egypt, he might at his pleaſure re-enter the country. But Philometor, appriſed of his deſign, invited his brother Phyſcon to an accommodation; which was happily effected by their ſiſter Cleopatra. In virtue of this agreement, the brothers were to reign jointly, and to oppoſe to the utmoſt of their power Antiochus, whom they conſidered as a

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* Lib. iii. 2, 3, 4, 5.

common enemy. On this the king of Syria invaded Egypt with a mighty army, but was prevented by the Romans from conquering it.

33 Difference between the two brothers decided by the Roman ſenate.

The two brothers were no ſooner freed from the apprehenſions of a foreign enemy than they began to quarrel with each other. Their differences ſoon came to ſuch a height, that the Roman ſenate interpoſed. But before the ambaſſadors employed to inquire into the merits of the cauſe could arrive in Egypt, Phyſcon had driven Philometor from the throne, and obliged him to quit the kingdom. On this the dethroned prince fled to Rome, where he appeared meanly dreſſed, and without attendants. He was very kindly received by the ſenate; who were ſo well ſatisfied of the injuſtice done him, that they immediately decreed his reſtoration. He was reconducted accordingly; and, on the arrival of the ambaſſadors in Egypt, an accommodation between the two brothers was negotiated. By this agreement, Phyſcon was put in poſſeſſion of Libya and Cyrene, and Philometor of all Egypt and the iſland of Cyprus; each of them being declared independent of the other in the dominion allotted to them. The treaty, as uſual, was confirmed with oaths and ſacrifices, and was broken almoſt as ſoon as made. Phyſcon was diſſatisfied with his ſhare of the dominions; and therefore ſent ambaſſadors to Rome, deſiring that the iſland of Cyprus might be added to his other poſſeſſions. This could not be obtained by the ambaſſadors; and therefore Phyſcon went to Rome in perſon. His demand was evidently unjuſt; but the Romans, conſidering that it was their intereſt to weaken the power of Egypt as much as poſſible, without further ceremony adjudged the iſland to him.

34 Iſland of Cyprus adjudged to Phyſcon.

Phyſcon ſet out from Rome with two ambaſſadors; and arriving in Greece on his way to Cyprus, he raiſed there a great number of mercenaries, with a deſign to ſail immediately to that iſland and conquer it. But the Roman ambaſſadors telling him, that they were commanded to put him in poſſeſſion of it by fair means and not by force, he diſmiſſed his army, and returned to Libya, while one of the ambaſſadors proceeded to Alexandria. Their deſign was to bring the two brothers to an interview on the frontiers of their dominions, and there to ſettle matters in an amicable manner. But the ambaſſador who went to Alexandria, found Philometor very averſe from compliance with the decree of the ſenate. He put off the ambaſſador ſo long, that Phyſcon ſent the other alſo to Alexandria, hoping that the joint perſuaſions of the two would induce Philometor to comply. But the king, after entertaining them at an immenſe charge for 40 days, at laſt plainly refuſed to ſubmit, and told the ambaſſadors that he was reſolved to adhere to the firſt treaty. With this anſwer the Roman ambaſſadors departed, and were followed by others from the two brothers. The ſenate, however, not only confirmed their decree in favour of Phyſcon, but renounced their alliance with Philometor, and commanded his ambaſſador to leave the city in five days.

35 Philometer refuſes to comply.

36 Rebellion againſt Phyſcon.

In the mean time, the inhabitants of Cyrene having heard unfavourable accounts of Phyſcon's behaviour during the ſhort time he reigned in Alexandria, conceived ſo ſtrong an averſion againſt him, that they reſolved to keep him out of their country by force of arms. On receiving intelligence of this reſolution, Phyſcon dropped all thoughts of Cyprus for the preſent; and haſtened with all his forces to Cyrene, where he ſoon got the better of his rebellious ſubjects, and eſtabliſhed himſelf in the kingdom. His vicious and tyrannical conduct, however, ſoon eſtranged from him the minds of his ſubjects, in ſuch a manner, that ſome of them entering into a conſpiracy againſt him, fell upon him one night as he was returning to his palace, wounded him in ſeveral places, and left him for dead on the ſpot. This he laid to the charge of his brother Philometor; and as ſoon as he was recovered, took another voyage to Rome. Here he made his complaints to the ſenate, and ſhowed them the ſcars of his wounds, accuſing his brother of having employed the aſſaſſins from whom he received them. Though Philometor was known to be a man of a moſt humane and mild diſpoſition, and therefore very unlikely to have been concerned in ſo black an attempt; yet the ſenate, being offended at his refuſing to ſubmit to their decree concerning the iſland of Cyprus, hearkened to this falſe accuſation; and carried their prejudice ſo far, that they not only refuſed to hear what his ambaſſadors had to ſay, but ordered them immediately to depart from the city. At the ſame time, they appointed five commiſſioners to conduct Phyſcon to Cyprus, and put him in poſſeſſion of that iſland, enjoining all their allies in thoſe parts to ſupply him with forces for that purpoſe.

37 He is defeated and taken priſoner by Philometor.

Phyſcon having by this means got together an army which ſeemed to him to be ſufficient for the accompliſhment of his deſign, landed in Cyprus; but being there encountered by Philometor in perſon, he was entirely defeated, and obliged to ſhelter himſelf in a city called *Lapitho*. Here he was cloſely beſieged, and at laſt obliged to ſurrender. Every one now expected that Phyſcon would have been treated as he deſerved; but his brother, inſtead of puniſhing, reſtored him to the government of Libya and Cyrene, adding ſome other territories inſtead of the iſland of Cyprus, and promiſing him his daughter in marriage. Thus an end was put to the war between the two brothers; for the Romans were aſhamed any longer to oppoſe a prince who had given ſuch a ſignal inſtance of his juſtice and clemency.

38 Death of Philometor.

On his return to Alexandria, Philometor appointed one Archias governor of Cyprus. But he, ſoon after the king's departure, agreed with Demetrius king of Syria, to betray the iſland to him for 500 talents. The treachery was diſcovered before it took effect; and the traitor, to avoid the puniſhment due to his crime, laid violent hands on himſelf. Ptolemy being offended with Demetrius for this attempt on Cyprus, joined Attalus king of Pergamus, and Ariarathes king of Cappadocia, in ſetting up a pretender to the crown of Syria. This was Alexander Balas; to whom he even gave his daughter Cleopatra in marriage, after he had placed him on the throne of Syria. But he, notwithſtanding theſe and many other favours, being ſuſpected of having entered into a plot againſt his benefactor, Ptolemy became his greateſt enemy; and marching againſt him, routed his army in the neighbourhood of Antioch. He did not, however, long enjoy his victory; for he died in a few days after the engegement, of the wounds he had received.

On the death of Philometor, Cleopatra the queen deſigned to ſecure the throne for her ſon. But ſome

39 Monſtrous wickedneſs of Phyſcon.

40 He is driven out.

of the principal nobility declaring for Phyſcon, a civil war was about to enſue, when matters were compromiſed on condition that Phyſcon ſhould marry Cleopatra, that he ſhould reign jointly with her during his life, and declare her ſon by Philometor heir to the crown. Theſe terms were no ſooner agreed upon than Phyſcon married Cleopatra, and, on the very day of the nuptials, murdered her ſon in her arms. This was only a prelude to the cruelties which he afterwards practiſed on his ſubjects. He was no ſooner ſeated on the throne, than he put to death all thoſe who had ſhown any concern for the murder of the young prince. He then wreaked his fury on the Jews, whom he treated more like ſlaves than ſubjects, on account of their having favoured the cauſe of Cleopatra. His own people were treated with little more ceremony. Numbers of them were every day put to death for the ſmalleſt faults, and often for no fault at all, but merely to gratify his inhuman temper. His cruelty towards the Alexandrians is particularly mentioned under the article ALEXANDRIA. In a ſhort time, being wearied of his queen, who was alſo his ſiſter, he divorced her; and married her daughter, who was alſo called *Cleopatra*, and whom he had previouſly raviſhed. In ſhort, his behaviour was ſo exceedingly wicked, that it ſoon became quite intolerable to his ſubjects; and he was obliged to fly to the iſland of Cyprus with his new queen, and *Memphitis*, a ſon he had by her mother.

41 Murders his ſon.

On the flight of the king, the divorced queen was placed on the throne by the Alexandrians; but Phyſcon, fearing leſt a ſon whom he had left behind ſhould be appointed king, ſent for him into Cyprus, and cauſed him to be aſſaſſinated as ſoon as he landed. This provoked the people againſt him to ſuch a degree, that they pulled down and daſhed to pieces all the ſtatues which had been erected to him at Alexandria. This the tyrant ſuppoſed to have been done at the inſtigation of the queen, and therefore reſolved to revenge it on her by killing his own ſon whom he had by her. He therefore, without the leaſt remorſe, cauſed the young prince's throat to be cut; and having put his mangled limbs into a box, ſent them as a preſent to his mother Cleopatra. The meſſenger with whom this box was ſent, was one of his guards. He was ordered to wait till the queen's birthday, which approached, and was to be celebrated with extraordinary pomp; and in the midſt of the general rejoicing, he was to deliver the preſent.

42 Phyſcon reſtored.

The horror and deteſtation occaſioned by this unexampled piece of cruelty cannot be expreſſed. An army was ſoon raiſed, and the command of it given to one *Marſyas*, whom the queen had appointed general, and enjoined to take all the neceſſary ſteps for the defence of the country. On the other hand, Phyſcon, having hired a numerous body of mercenaries, ſent them, under the command of one *Hegelochus*, againſt the Egyptians. The two armies met on the frontiers of Egypt, on which a bloody battle enſued; but at laſt the Egyptians were entirely defeated, and Marſyas was taken priſoner. Every one expected that the captive general would have been put to death with the ſevereſt torments; but Phyſcon, perceiving that his cruelties only exaſperated the people, reſolved to try whether he could regain their affections by lenity; and therefore pardoned Marſyas, and ſet him at liberty.—Cleopatra, in the mean time, being greatly diſtreſſed by this overthrow, demanded aſſiſtance from Demetrius king of Syria, who had married her eldeſt daughter by Philometor, promiſing him the crown of Egypt for his reward. Demetrius accepted the propoſal without heſitation, marched with all his forces into Egypt, and there laid ſiege to Peluſium. But he being no leſs hated in Syria than Phyſcon was in Egypt, the people of Antioch, taking advantage of his abſence, revolted againſt him, and were joined by moſt of the other cities in Syria. Thus Demetrius was obliged to return; and Cleopatra, being now in no condition to oppoſe Phyſcon, fled to Ptolemais, where her daughter the queen of Syria at that time reſided. Phyſcon was then reſtored to the throne of Egypt, which he enjoyed without further moleſtation till his death; which happened at Alexandria, in the 29th year of his reign, and 67th of his age.

43 Ptolemy Lathyrus driven out, and Alexander ſet up.

To Phyſcon ſucceeded Ptolemy Lathyrus, about 122 years before Chriſt; but he had not reigned long, before his mother, finding that he would not be entirely governed by her, by falſe ſurmiſes ſtirred up the Alexandrians, who drove him from the throne, and placed on it his youngeſt brother Alexander. Lathyrus after this was obliged to content himſelf with the government of Cyprus, which he was permitted to enjoy in quiet. Ptolemy Alexander, in the mean time, finding he was to have only the ſhadow of ſovereignty, and that his mother Cleopatra was to have all the power, ſtole away privately from Alexandria. The queen uſed every artifice to bring him back, as well knowing that the Alexandrians would never ſuffer her to reign alone. At laſt her ſon yielded to her entreaties; but ſoon after, underſtanding that ſhe had hired aſſaſſins to deſpatch him, he cauſed her to be murdered.

44 Lathyrus reſtored.

The death of the queen was no ſooner known to the Alexandrians, than, diſdaining to be commanded by a parricide, they drove out Alexander, and recalled Lathyrus.—The depoſed prince for ſome time led a rambling life in the iſland of Cos; but having got together ſome ſhips, he, the next year, attempted to return into Egypt. But being met by *Tyrrhus*, Lathyrus's admiral, he was defeated, and obliged to fly to Myra in Lycia. From Myra he ſteered his courſe towards Cyprus, hoping that the inhabitants would place him on the throne, inſtead of his brother. But *Chareas*, another of Lathyrus's admirals, coming up with him while he was ready to land, an engagement enſued, in which Alexander's fleet was diſperſed, and he himſelf killed.

45 Cyrenaica bequeathed to the Romans.

During theſe diſturbances, *Apion* king of Cyrenaica, the ſon of Ptolemy Phyſcon by a concubine, having maintained peace and tranquillity in his dominions during a reign of 21 years, died, and by his will left his kingdom to the Romans; and thus the Egyptian empire was conſiderably reduced and circumſcribed.

46 City of Thebes ruined.

Lathyrus being now delivered from all competitors, turned his arms againſt the city of Thebes, which had revolted from him. The king marched in perſon againſt the rebels; and, having defeated them in a pitched battle, laid cloſe ſiege to their city. The inhabitants defended themſelves with great reſolution for three years. At laſt, however, they were obliged to ſubmit, and the city was given up to be plundered by the ſoldiery. They left everywhere the moſt melancholy monuments of their avarice and cruelty; ſo that Thebes, which till that time had been one of the moſt wealthy cities of Egypt, was now reduced ſo low that it never afterwards made any figure.

47
Alexander II. ſucceeds Lathyrus.

48
Marries Cleopatra, and murders her.

About 76 years before Chriſt, Ptolemy Lathyrus was ſucceeded by Alexander II. He was the ſon of the Ptolemy Alexander for whom Lathyrus had been driven out; and had met with many adventures. He was firſt ſent by Cleopatra into the iſland of Cos, with a great ſum of money, and all her jewels; as thinking that was the ſafeſt place where they could be kept. When Mithridates king of Pontus made himſelf maſter of that iſland, the inhabitants delivered up to him the young Egyptian prince, together with all the treaſures. Mithridates gave him an education ſuitable to his birth; but he, not thinking himſelf ſafe with a prince who had ſhed the blood of his own children, fled to the camp of Sylla the Roman dictator, who was then making war in Aſia. From that time he lived in the family of the Roman general, till news was brought to Rome of the death of Lathyrus. Sylla then ſent him to Egypt to take poſſeſſion of the throne. But, before his arrival, the Alexandrians had choſen Cleopatra for their ſovereign. To compromiſe matters, however, it was agreed, that Ptolemy ſhould marry her, and take her for his partner in the throne. This was accordingly done; and 19 days after the marriage, the unhappy queen was murdered by her huſband, who for 15 years afterwards ſhowed himſelf ſuch a monſter of wickedneſs, that a general inſurrection at laſt enſued among his ſubjects, and he was obliged to fly to Pompey the Great, who was then carrying on the war againſt Mithridates king of Pontus. But Pompey refuſing to concern himſelf in the matter, he retired to the city of Tyre, where he died ſome months after.

49
Leaves his kingdom to the Romans.

When he was forced to ſhut himſelf up in the city of Tyre, Alexander had ſent ambaſſadors to Rome, in order to influence the ſenate in his favour. But, dying before the negociation was finiſhed, he made over by his laſt will all his rights to the Roman people, declaring them heirs to his kingdom: not out of any affection to the republic; but with a view to raiſe diſputes between the Romans and his rival Auletes, whom the Egyptians had placed on the throne. The will was brought to Rome, where it occaſioned warm debates. Some were for taking immediate poſſeſſion of the kingdom. Others thought that no notice ſhould be taken of ſuch a will, becauſe Alexander had no right to diſpoſe of his dominions in prejudice of his ſucceſſor, and to exclude from the crown thoſe who were of the royal family of Egypt. Cicero repreſented, that ſuch a notorious impoſition would debaſe the majeſty of the Roman people, and involve them in endleſs wars and diſputes; that the fruitful fields of Egypt would be a ſtrong temptation to the avarice of the people, who would inſiſt on their being divided among them; and laſtly, that by this means the bloody quarrels about the Agrarian laws would be revived. Theſe reaſons had ſome weight with the ſenate; but what chiefly prevented them from ſeizing on Egypt at this time was, that they had lately taken poſſeſſion of the kingdom of Bithynia in virtue of the will of Nicomedes, and of Cyrene and Libya by the will of Apion. They thought, therefore, that if they ſhould, on the like pretence, take poſſeſſion of the kingdom of Egypt, this might too much expoſe their deſign of ſetting up a kind of univerſal monarchy, and occaſion a formidable combination againſt them.

50
Character of Auletes the new king.

51
Is acknowledged by the Romans.

52
Is driven from the throne, and flies to Rome.

Auletes, who was now raiſed to the throne by the Egyptians, is ſaid to have ſurpaſſed all the kings that went before him in the effeminacy of his manners. The name *Auletes*, which ſignifies the *flute-player*, was given him becauſe he piqued himſelf on his ſkill in performing upon that inſtrument, and was not aſhamed even to contend for the prize in the public games. He took great pleaſure in imitating the manners of the Bacchanals; dancing in a female dreſs, and in the ſame meaſures that they uſed during the ſolemnity of their god Bacchus, and hence he had the ſurname of the *New Dionyſius* or *Bacchus*. As his title to the crown was diſputable (he being only the ſon of a concubine), the firſt care of Auletes was to get himſelf acknowledged by the Romans, and declared their ally. This was obtained by applying to Julius Cæſar, who was at that time conſul, and immenſely in debt. Cæſar being glad of ſuch an opportunity of raiſing money, made the king of Egypt pay pretty dear for his alliance. Six thouſand talents, a ſum equal to 1,162,500l. Sterling, were paid partly to Cæſar himſelf, and partly to Pompey, whoſe intereſt was neceſſary for obtaining the conſent of the people. Though the revenues of Egypt amounted to twice this ſum, yet Auletes found it impoſſible for him to raiſe it without ſeverely taxing his ſubjects. This occaſioned a general diſcontent; and while the people were almoſt ready to take up arms, a moſt unjuſt decree paſſed at Rome for ſeizing the iſland of Cyprus. When the Alexandrians heard of the intentions of the republic, they preſſed Auletes to demand that iſland as an ancient appendage of Egypt; and, in caſe of a refuſal, to declare war againſt that haughty and imperious people, who, they now ſaw, though too late, aimed at nothing leſs than the ſovereignty of the world. With this requeſt the king refuſed to comply; upon which his ſubjects, already provoked beyond meaſure at the taxes with which they were loaded, flew to arms, and ſurrounded the palace. The king had the good luck to eſcape their fury, and immediately leaving Alexandria, ſet ſail for Rome.

53
Cato's advice to him.

In his way to that city, he landed on the iſland of Rhodes, where the famous Cato at that time was, being on his way to Cyprus, to put the unjuſt decree of the ſenate in execution. Auletes, deſirous to confer with a man of his prudence, immediately ſent to acquaint him with his arrival. He imagined, that, upon this notice, Cato would immediately come and wait upon him; but the proud Roman told the meſſenger, that if the king of Egypt had any thing to ſay to Cato, he might, if he thought proper, come to his houſe. Accordingly the king went to pay him a viſit; but was received with very little ceremony by Cato, who did not even vouchſafe to riſe out of his ſeat when he came into his preſence. When Auletes had laid his affairs before this haughty republican, he was blamed by him for leaving Egypt, the richeſt kingdom in the world, in order to expoſe himſelf, as he ſaid, to the indignities he would meet with at Rome. There Cato told him, that nothing was in requeſt but wealth and grandeur. All the riches of Egypt, he ſaid, would not be ſufficient to ſatisfy the avarice of the leading men in Rome. He therefore adviſed him to return to Egypt; and ſtrive, by a more equitable conduct, to regain the affections of his people. He even offered to reconduct him thither, and employ his good offices in his behalf. But though Ptolemy was ſenſible of the propriety of this advice, the friends he had with him diſſuaded him from following it, and accordingly he ſet out for Rome.

54
Infamous conduct of Auletes.

On his arrival in this metropolis, the king found, to his great concern, that Cæſar, in whom he placed his greateſt confidence, was then in Gaul. He was received, however, by Pompey with great kindneſs. He aſſigned him an apartment in his own houſe, and omitted nothing that lay in his power to ſerve him. But, notwithſtanding the protection of ſo powerful a man, Auletes was forced to go from houſe to houſe like a private perſon, ſoliciting the votes of the ſenators. After he had ſpent immenſe treaſures in procuring a ſtrong party in the city, he was at laſt permitted to lay his complaints before the ſenate; and at the ſame time there arrived an embaſſy from the Alexandrians, conſiſting of 100 citizens, to acquaint the ſenate with the reaſons of their revolt.

55
Berenice raiſed to the throne of Egypt.

When Auletes firſt ſet out for Rome, the Alexandrians, not knowing what was become of him, placed on the throne his daughter Berenice; and ſent an embaſſy into Syria to Antiochus Aſiaticus, inviting him into Egypt to marry the queen, and reign in partnerſhip with her. Antiochus was dead before the arrival of the ambaſſadors; upon which the ſame propoſal was made to his brother Seleucus, who readily accepted it. This Seleucus is deſcribed by Strabo as monſtrouſly deformed in body, and ſtill more ſo in mind. The Egyptians nicknamed him *Cybioſactes*, or *the Scullion*; a name which ſeemed more fit for him than any other. He was ſcarce ſettled on the throne, when he gave a ſignal inſtance of his ſordid and avaricious temper. Ptolemy the firſt had cauſed the body of Alexander the Great to be depoſited in a coffin of maſſy gold. This the king ſeized upon; and by that means provoked his wife Berenice to ſuch a degree, that ſhe cauſed him to be murdered. She then married one Archelaus, high prieſt of Comana in Pontus, who pretended to be the ſon of Mithridates the Great; but was, in fact, only the ſon of that monarch's general.

56
She marries Seleucus, and murders him.

57
Marries Archelaus.

Auletes was not a little alarmed on hearing of theſe tranſactions, eſpecially when the ambaſſadors arrived, which he feared would overturn all the ſchemes he had laboured ſo much to bring about. The embaſſy was headed by one Dion, a celebrated Academic philoſopher who had many powerful friends at Rome. But Ptolemy found means to get both him and moſt of his followers aſſaſſinated; and this intimidated the reſt to ſuch a degree, that they durſt not execute their commiſſion, or, for ſome time, even demand juſtice for the murder of their colleagues.

58
Auletes murders the Egyptian ambaſſadors.

The report of ſo many murders, however, at laſt ſpread a general alarm. Auletes, ſure of the protection of Pompey, did not ſcruple to own himſelf the perpetrator of them. Nay, though an action was commenced againſt one Aſcitius, an aſſaſſin, who had ſtabbed Dion the chief of the embaſſy above mentioned, and the crime was fully proved; yet he was acquitted by the venal judges, who had all been bribed by Ptolemy. In a ſhort time, the ſenate paſſed a decree, by which it was enacted, that the king of Egypt ſhould be reſtored by force of arms. All the great men in Rome were ambitious of this commiſſion; which, they well knew, would be attended with immenſe profit. Their conteſts on this occaſion took up a conſiderable time; and at laſt a prophecy of the Sybil was found out, which forbade the aſſiſting an Egyptian monarch with an army. Ptolemy, therefore, wearied out with ſo long a delay, retired from Rome, where he had made himſelf generally odious, to the temple of Diana at Epheſus, there to wait the deciſion of his fate. Here he remained a conſiderable time: but as he ſaw that the ſenate came to no reſolution, though he had ſolicited them by letters ſo to do; at laſt, by Pompey's advice, he applied to Gabinius the proconſul of Syria. This Gabinius was a man of a moſt infamous character, and ready to undertake any thing for money. Therefore, though it was contrary to an expreſs law for any governor to go out of his province without poſitive orders from the ſenate and people of Rome, yet Gabinius ventured to tranſgreſs this law, upon condition of being well paid for his pains. As a recompenſe for his trouble, however, he demanded 10,000 talents; that is, 1,937,500l. ſterling. Ptolemy, glad to be reſtored on any terms, agreed to pay the above-mentioned ſum; but Gabinius would not ſtir till he had received one half of it. This obliged the king to borrow it from a Roman knight named *Caius Rabirius Poſthumius*; Pompey interpoſing his credit and authority for the payment of the capital and intereſt.

59
His reſtoration decreed by the ſenate.

60
Gabinius undertakes to reſtore him for a great ſum.

Gabinius now ſet out for Egypt, attended by the famous Mark Antony, who at this time ſerved in the army under him. He was met by Archelaus, who ſince the departure of Auletes had reigned in Egypt jointly with Berenice, at the head of a numerous army. The Egyptians were utterly defeated, and Archelaus taken priſoner in the firſt engagement. Thus Gabinius might have put an end to the war at once: but his avarice prompted him to diſmiſs Archelaus on his paying a conſiderable ranſom; after which, pretending that he had made his eſcape, freſh ſums were demanded from Ptolemy for defraying the expences of the war. For theſe ſums Ptolemy was again obliged to apply to Rabirius, who lent him what money he wanted at a very high intereſt. At laſt, however, Archelaus was defeated and killed, and thus Ptolemy again became maſter of all Egypt.

61
Archelaus defeated and killed.

62
Berenice put to death and the people oppreſſed.

No ſooner was Auletes firmly ſettled on the throne, than he put to death his daughter Berenice, and oppreſſed his people with the moſt cruel exactions, in order to procure the money he had been obliged to borrow while in a ſtate of exile. Theſe oppreſſions and exactions the cowardly Egyptians bore with great patience, being intimidated by the garriſon which Gabinius had left in Alexandria. But neither the fear of the Romans, nor the authority of Ptolemy, could make them put up an affront offered to their religion. A Roman ſoldier happened to kill a cat, which was an animal held ſacred and even worſhipped by the Egyptians; and no ſooner was this ſuppoſed ſacrilege known, than the Alexandrians made a general inſurrection, and, gathering together in crowds, made their way through

through the Roman guards, dragged the ſoldier out of his houſe, and, in ſpite of all oppoſition, tore him in pieces.

63
Ingratitude of Auletes.

Notwithſtanding the heavy taxes, however, which Ptolemy laid on his people, it doth not appear that he had any deſign of paying his debts. Rabirius, who, as we have already obſerved, had ſent him immenſe ſums, finding that the king affected delays, took a voyage to Egypt, in order to expoſtulate with him in perſon. Ptolemy paid very little regard to his expoſtulations; but excuſed himſelf on account of the bad ſtate of his finances. For this reaſon he offered to make Rabirius collector general of his revenues, that he might in that employment pay himſelf. The unfortunate creditor accepted the employment for fear of loſing his debt. But Ptolemy, ſoon after, upon ſome frivolous pretence or other, cauſed him and all his ſervants to be cloſely confined. This baſe conduct exaſperated Pompey as much as Rabirius; for the former had been in a manner ſecurity for the debt, as the money had been lent at his requeſt, and the buſineſs tranſacted at a country houſe of his near Alba. However, as Rabirius had reaſon to fear the worſt, he took the firſt opportunity of making his eſcape, glad to get off with life from his cruel and faithleſs debtor. To complete his misfortunes, he was proſecuted at Rome as ſoon as he returned, 1. For having enabled Ptolemy to corrupt the ſenate with ſums lent him for that purpoſe. 2. For having debaſed and diſhonoured the character of a Roman knight, by farming the revenues, and becoming the ſervant of a foreign prince. 3. For having been an accomplice with Gabinius, and ſharing with him the 10,000 talents which that proconſul had received for his Egyptian expedition. By the eloquence of Cicero he was acquitted; and one of the beſt orations to be found in the writings of that author was compoſed on this occaſion. Gabinius was alſo proſecuted; and, as Cicero ſpoke againſt him, he very narrowly eſcaped death. He was, however, condemned to perpetual baniſhment, after having been ſtripped of all he was worth. He lived in exile till the time of the civil wars, when he was recalled by Cæſar, in whoſe ſervice he loſt his life.

64
Leaves his children to the care of the Romans.

Auletes enjoyed the throne of Egypt about four years after his re-eſtabliſhment; and at his death left his children, a ſon and two daughters, under the tuition of the Roman people. The name of the ſon was *Ptolemy*, thoſe of the daughters were *Cleopatra* and *Arſinoe*. This was the Cleopatra who afterwards became ſo famous, and had ſo great a ſhare in the civil wars of Rome. As the tranſactions of the preſent reign, however, are ſo cloſely connected with the affairs of Rome, that they cannot be well underſtood without knowing the ſituation of the Romans at that time, we refer for an account of them to the *Hiſtory of* ROME.

65
State of Egypt till its conqueſt by the caliph of Cairwan.

With Cleopatra ended the family of Ptolemy Lagus, the founder of the Grecian empire in Egypt, after it had held that country in ſubjection for the ſpace of 294 years. From this time Egypt became a province of the Roman empire, and continued ſubject to the emperors of Rome or Conſtantinople. In the year 642, it was conquered by the Arabs under Amru Ebn al As, one of the generals of the caliph Omar. In the year 889, an independent government was ſet up in this kingdom by Ahmed Ebn Tolun, who rebelled againſt Al Mokhadi caliph of Bagdad. It continued to be governed by him and his ſucceſſors for 27 years, when it was again reduced by Al Moctaſi caliph of Bagdad. In about 30 years after, we find it again an independent ſtate, being joined with Syria under Mahomet Ebn Taj, who had been appointed governor of theſe provinces. This government, however, was alſo but ſhort-lived; for in the year 968 it was conquered by Jawhar, one of the generals of Moez Ledinillah, the Fatemite caliph of Cairwan in Barbary. See BARBARY, N° 34.

66
Moez takes poſſeſſion of his new kingdom.

No ſooner was Moez informed of the ſucceſs of his general, than he prepared with all expedition to go and take poſſeſſion of his new conqueſt. Accordingly he ordered all the vaſt quantities of gold which he and his predeceſſors had amaſſed, to be caſt into ingots of the ſize and figure of the millſtones uſed in hand mills, and conveyed on camels backs into Egypt. To ſhow that he was fully determined to abandon his dominions in Barbary, and to make Egypt the reſidence of himſelf and his ſucceſſors, he cauſed the remains of the three former princes of his race to be removed from Cairwan in Barbary, and to be depoſited in a ſtately moſque erected for that purpoſe in the city of Cairo in Egypt. This was a moſt effectual method to induce his ſucceſſors to reſide in Egypt alſo, as it was become an eſtabliſhed cuſtom and duty among thoſe princes frequently to pay their reſpectful viſits to the tombs of their anceſtors.

67
Will not ſuffer prayers to be ſaid for the caliph of Bagdad.

To eſtabliſh himſelf the more effectually in his new dominions, Moez ſuppreſſed the uſual prayers made in the moſques for the caliphs of Bagdad, and ſubſtituted his own name in their ſtead. This was complied with, not only in Egypt and Syria, but even throughout all Arabia, the city of Mecca alone excepted. The conſequence was, a ſchiſm in the Mahommedan faith, which continued upwards of 200 years, and was attended with continual anathemas, and ſometimes deſtructive wars, between the caliphs of Bagdad and of Egypt.—Having fully eſtabliſhed himſelf in his kingdom, he died in the 45th year of his age, three years after he had left his dominions in Barbary; and was ſucceeded by his ſon Abu Al Manſur Barar, ſurnamed Aziz Billah.

68
Unſucceſsful expedition into Syria.

The new caliph ſucceeded to the throne at the age of 21; and committed the management of affairs entirely to the care of Jawhar, his father's long-experienced general and prime miniſter. In 978, he ſent this famous warrior to drive out Al Aftekin, the emir of Damaſcus. The Egyptian general accordingly formed the ſiege of that place; but at the end of two months, was obliged to raiſe it, on the approach of an army of Karmatians under the command of Al Hakem. As Jawhar was not ſtrong enough to venture an engagement with theſe Karmatians, it was impoſſible for him to hinder them from effecting a junction with the forces of Al Aftekin. He therefore retreated, or rather fled, towards Egypt with the utmoſt expedition; but being overtaken by the two confederate armies, he was ſoon reduced to the laſt extremity. He was, however, permitted to reſume his march, on condition that he paſſed under Al Aftekin's ſword and Al Hakem's lance; and to this diſgraceful condition Jawhar found himſelf obliged to ſubmit. On his arrival in Egypt, he immediately adviſed Al Aziz to undertake an expedition in perſon into the eaſt, againſt the combined army of Turks, Karmatians, and Damaſcenes, under the command of Al Aftekin and Al Hakem. The caliph followed his advice; and advancing againſt his enemies, overthrew them with great ſlaughter. Al Aftekin himſelf eſcaped out of the battle; but was afterwards taken and brought to Al Aziz, who made him his chamberlain, and treated him with great kindneſs. Jawhar, in the mean time, was diſgraced on account of his bad ſucceſs: and in his diſgrace he continued till his death, which happened in the year of our Lord, 990, and of the Hegira 381.

69
Aleppo beſieged without ſucceſs.

This year Al Aziz having received advice of the death of Saado'dawla prince of Aleppo, ſent a formidable army under the command of a general named *Manjubekin*, to reduce that place. Lulu, who had been appointed guardian to Saado'dawla's ſon, finding himſelf preſſed by the Egyptians, who carried on the ſiege with great vigour, demanded aſſiſtance from the Greek emperor. Accordingly, he ordered a body of troops to advance to Lulu's relief. Manjubekin, being informed of their approach, immediately raiſed the ſiege, and advanced to give them battle. An obſtinate engagement enſued, in which the Greeks were at laſt overthrown with great ſlaughter. After this victory, Manjubekin puſhed on the ſiege of Aleppo very briſkly; but finding the place capable of defending itſelf much longer than he at firſt imagined, and his proviſions beginning to fail, he raiſed the ſiege. The caliph upon this ſent him a very threatening letter, and commanded him to return before Aleppo. He did ſo; and continued the ſiege for 13 months; during all which time it was defended by Lulu with incredible bravery. At laſt, the Egyptians hearing that a numerous army of Greeks was on their way to relieve the city, they raiſed the ſiege, and fled with the utmoſt precipitation. The Greeks then took and plundered ſome of the cities which Al Aziz poſſeſſed in Syria; and Manjubekin made the beſt of his way to Damaſcus, where he ſet up for himſelf. Al Aziz being informed of this revolt, marched in perſon againſt him with a conſiderable army; but being taken ill by the way, he expired, in the 21ſt year of his reign and 42d of his age.

Al Aziz was ſucceeded by his ſon Abu Al Manſur, ſurnamed Al Hakem; who, being only 11 years of age, was put under the tuition of a eunuch of approved integrity.

70
Strange madneſs of the caliph Al Hakem.

This reign is remarkable for nothing ſo much as the madneſs with which the caliph was ſeized in the latter part of it. This manifeſted itſelf firſt by his iſſuing many prepoſterous edicts; but at length grew to ſuch a height, that he fancied himſelf a god, and found no fewer than 16,000 perſons who owned him as ſuch. Theſe were moſtly the Dararians, a new ſect ſprung up about this time, who were ſo called from their chief, Mohammed Ebn Iſhmael, ſurnamed Darari. He is ſuppoſed to have inſpired the mad caliph with this impious notion; and, as Darari ſet up for a ſecond Moſes, he did not ſcruple to aſſert that Al Hakem was the great Creator of the univerſe. For this reaſon, a zealous Turk ſtabbed him in the caliph's chariot. His death was followed by a three days uproar in the city of Cairo; during which, Darari's houſe was pulled down, and many of his followers maſſacred. The ſect, however, did not expire with its author. He left behind him a diſciple named Hamza, who, being encouraged by the mad caliph, ſpread it far and wide through his dominions. This was quickly followed by an abrogation of all the Mahommedan faſts, feſtivals, and pilgrimages, the grand one to Mecca in particular; ſo that the zealous Mahometans were now greatly alarmed, as juſtly ſuppoſing that Al Hakem deſigned entirely to ſuppreſs the worſhip of the true God, and introduce his own in its place. From this apprehenſion, however, they were delivered by the death of the caliph; who was aſſaſſinated, by a contrivance of his own ſiſter, in the year 1020.

Al Hakem was ſucceeded by his ſon Al Thaher, who reigned 15 years; and left the throne to a ſon under ſeven years of age, named Al Moſtanſer Billah.—In the year 1041, a revolt happened in Syria; but Al Moſtanſer having ſent a powerful army into that country, under the command of one *Anuſhtekin*, he not only reduced the rebels, but conſiderably enlarged the Egyptian dominions in Syria.

71
Al Moſtanſer attempts the conqueſt of Bagdad.

In 1054, a Turk named Al Baſſaſiri, having quarrelled with the vizir of Al Kayem caliph of Bagdad, fled to Egypt, and put himſelf under the protection of Al Moſtanſer. The latter, imagining this would be a favourable opportunity for enlarging his dominions, and perhaps ſeizing on the city of Bagdad, ſupplied Baſſaſiri with money and troops. By this aſſiſtance, he was enabled to poſſeſs himſelf of Arabian Irak, and ravaged that province to the very gates of Bagdad. On this, Al Kayem wrote to Togrol Beg, or Tangrolipix, the Turkiſh ſultan, who poſſeſſed very extenſive dominions in the eaſt, to come to his aſſiſtance. The ſultan immediately complied with his requeſt, and ſoon arrived at Bagdad with a formidable army and 18 elephants. Of this Baſſaſiri gave notice to Al Moſtanſer, and entreated him to exert himſelf further for his ſupport againſt ſo powerful an enemy. This was accordingly done, but nothing worthy of notice happened till the year 1058. At this time Baſſaſiri having found means to excite Ibrahim the ſultan's brother to a revolt, Togrol Beg was obliged to employ all his force againſt him. This gave Baſſaſiri an opportunity of ſeizing on the city of Bagdad itſelf; and the unfortunate caliph, according to ſome, was taken priſoner, or, accordingly to others, fled out of the city. Baſſaſiri, on his entry, cauſed Al Moſtanſer to be immediately proclaimed caliph in all quarters of the city. Al Kayem's vizir he cauſed to be led on a camel through the ſtreets of Bagdad, dreſſed in a woollen gown, with a high red bonnet, and a leathern collar about his neck; a man laſhing him all the way behind. Then being ſewed up in a bull's hide, with the horns placed over his head, and hung upon hooks, he was beaten without ceaſing till he died. The imperial palace was plundered, and the caliph himſelf detained a cloſe priſoner.

72
Caliph of Bagdad aſſiſted by Togrol Beg.

73
Bagdad taken.

74
The caliph reſtored.

This ſucceſs was but ſhort-lived; for, in 1059, Togrol Beg defeated his brother Ibrahim, took him priſoner, and ſtrangled him with a bow ſtring. He then marched to Bagdad, which Baſſaſiri thought proper to abandon at his approach. Here the caliph Al Kayem was delivered up by Mahras, the governor of a city called *Haditha*, who had the charge of him. The caliph

caliph was immediately reſtored to his dignity; which Baſſaſiri no ſooner underſtood, than he again advanced towards the city. Againſt him Togrol Beg ſent a part of his army under ſome of his generals, while he himſelf followed with the reſt. A battle enſued, in which the army of Baſſaſiri was defeated, and he himſelf killed. His head was brought to Togrol Beg, who cauſed it to be carried on a pike through the ſtreets of Bagdad.

75 Decline of the Egyptian empire.

Thus the hopes of Al Moſtanſer were entirely fruſtrated; and from this period we may date the declenſion of the Egyptian empire under the caliphs. They had made themſelves maſters of almoſt all Syria; but no ſooner was Baſſaſiri's bad ſucceſs known, than the younger part of the citizens of Aleppo revolted, and ſet up Mahmud Azzo'dawla, who immediately laid ſiege to the citadel. Al Moſtanſer ſent a powerful army againſt him, which Azzo'dawla entirely defeated, and took the general himſelf priſoner; and ſoon after this, he made himſelf maſter both of the city and citadel, with all their dependencies. In his new dominions he behaved with the greateſt cruelty, deſtroying every thing with fire and ſword, and making frequent incurſions into the neighbouring provinces, which he treated in the ſame manner.

76 Terrible famine and plague.

This diſaſter was ſoon followed by others ſtill more terrible. In 1066, a famine raged over all Egypt and Syria, with ſuch fury, that dogs and cats were ſold for four or five Egyptian dinars each, and other proviſions in proportion. Multitudes of people died in Cairo for want of food. Nay, ſo great was the ſcarcity, that the vizir had but one ſervant left who was able to attend him to the caliph's palace, and to whom he gave the care of his horſe when he alighted at the gate. But at his return, he was ſurpriſed to find that the horſe had been carried off, killed and eaten by the famiſhed people. Of this he complained to the caliph; who cauſed three of them who had carried off the horſe to be hanged. Next day, however, he was ſtill more ſurpriſed to hear, that all the fleſh had been picked off the bones of the three unhappy criminals, ſo that nothing but the ſkeletons were left. And to ſuch a degree of miſery were the inhabitants, not only in Cairo but through all Egypt, reduced, that the carcaſes of thoſe who died were ſold for food at a great price, inſtead of being buried. All this time the caliph ſhowed the greateſt kindneſs and beneficence towards his unhappy ſubjects; inſomuch that of 10,000 horſes, mules, and camels, which he had in his ſtables when the famine began, he had only three left when it was removed.

77 Invaded by the Turks.

The famine was followed by a plague; and this by an invaſion of the Turks under Abu Ali Al Haſan Naſerod'dawla, the very general who had been ſent againſt the rebel Azzo'dawla and defeated by him. He began with beſieging the caliph in his own palace; and the unhappy prince, being in no condition to make reſiſtance, was obliged to buy himſelf off at the expence of every thing valuable that was left in his exhauſted capital and treaſury. This, however, did not hinder thoſe mercileſs plunderers from ravaging all the Lower Egypt from Cairo to Alexandria, and committing the moſt horrid cruelties through that whole tract.—This happened in the years 1067 and 1068; and in 1069 and 1070, there happened two other revolts in Syria: ſo that this country was now almoſt entirely loſt.

78 Jeruſalem taken.

In 1095 died the caliph Al Moſtanſer, having reigned 60 years; and was ſucceeded by his ſon Abul Kaſem, ſurnamed Al Moſtali. The moſt remarkable tranſaction of this prince's reign, was his taking the city of Jeruſalem from the Turks in 1098; but this ſucceſs was only of ſhort duration; for it was the ſame year taken by the cruſaders.

79 Revolution in the kingdom.

From this time to the year 1164, the Egyptian hiſtory affords little elſe than an account of the inteſtine broils and conteſts between the vizirs or prime miniſters, who were now become ſo powerful, that they had in a great meaſure ſtripped the caliphs of their civil power, and left them nothing but a ſhadow of ſpiritual dignity. Theſe conteſts at laſt gave occaſion to a revolution, by which the race of Fatemite caliphs was totally extinguiſhed. This revolution was accompliſhed in the following manner. One *Shawer*, having overcome all his competitors, became vizir to Al Aded, the eleventh caliph of Egypt. He had not been long in poſſeſſion of this office, when Al Dargam, an officer of rank, endeavoured to deprive him of it. Both parties quickly had recourſe to arms; and a battle enſued, in which Shawer was defeated, and obliged to fly to Nuroddin prince of Syria, by whom he was graciouſly received, and who promiſed to reinſtate him in his office of vizir. As an inducement to Nuroddin to aſſiſt him more powerfully, Shawer told him that the cruſaders had landed in Egypt, and made a conſiderable progreſs in the conqueſt of it. He promiſed alſo, that, in caſe he was reinſtated in his office, he would pay Nuroddin annually the third part of the revenues of Egypt; and would, beſides, defray the whole expence of the expedition.

As Nuroddin bore an implacable hatred to the Chriſtians, he readily undertook an expedition againſt them, for which he was to be ſo well paid. He therefore ſent an army into Egypt under the command of Shawer and a general named *Aſadoddin*. Dargam, in the mean time, had cut off ſo many generals whom he imagined favourable to Shawer's intereſt, that he thereby weakened the military force of the kingdom, and in a great meaſure deprived himſelf of the power of reſiſtance. He was therefore eaſily overthrown by Aſadoddin, and Shawer reinſtated in the office of vizir. The faithleſs miniſter, however, no ſooner ſaw himſelf firmly eſtabliſhed in his office, than he refuſed to fulfil his engagements to Nuroddin by paying the ſtipulated ſums. Upon this, Aſadoddin ſeized Peluſium and ſome other cities. Shawer then entered into an alliance with the cruſaders, and Aſadoddin was beſieged by their combined forces in Peluſium. Nuroddin, however, having invaded the Chriſtian dominions in Syria, and taken a ſtrong fortreſs called *Harem*, Shawer and his confederates thought proper to hearken to ſome terms of accommodation, and Aſadoddin was permitted to depart for Syria.

In the mean time, Nuroddin, having ſubdued the greateſt part of Syria and Meſopotamia, reſolved to make Shawer feel the weight of his reſentment on account of his perfidious conduct. He therefore ſent back Aſadoddin into Egypt with a ſufficient force, to compel Shawer to fulfil his engagements: but this the vizir took care to do before the arrival of Aſadoddin; and thus, for the preſent, avoided the danger. It was not long, however, before he gave Nuroddin freſh occaſion to ſend this general againſt him. That prince had now driven the cruſaders almoſt entirely out of Syria, but was greatly alarmed at their progreſs in Egypt; and conſequently offended at the alliance which Shawer had concluded with them, and which he ſtill perſiſted in obſerving. This treaty was alſo thought to be contrived on purpoſe to prevent Shawer from being able to fulfil his promiſe to Nuroddin, of ſending him annually a third of the revenues of Egypt. Nuroddin therefore again deſpatched Aſadoddin into Egypt, in the year 1166, with a ſufficient force, and attended by the famous Salahaddin, or Saladin, his own nephew. They entered the kingdom without oppoſition, and totally defeated Shawer and the cruſaders. They next made themſelves maſters of Alexandria; and, after that, overran all the Upper Egypt. Saladin was left with a conſiderable garriſon in Alexandria; but Aſadoddin was no ſooner gone, than the cruſaders laid ſiege to that city. This at laſt obliged Aſadoddin to return to its relief. The great loſſes he had ſuſtained in this expedition probably occaſioned his agreeing to a treaty with Shawer, by which he engaged to retire out of Egypt, upon being paid a ſum of money.

Aſadoddin was no ſooner gone, than Shawer entered into a freſh treaty with the Franks. By this new alliance he was to attack Nuroddin in his own dominions, as he was at that time engaged in quelling ſome revolters, which would effectually prevent his ſending any more forces into Egypt. This treaty ſo provoked the Syrian prince, that he reſolved to ſuſpend his other conqueſts for ſome time, and exert his whole ſtrength in the conqueſt of Egypt.

80
Conqueſts of the cruſaders.

By this time the cruſaders had reduced Peluſium, and made a conſiderable progreſs in the kingdom, as well as in ſome other countries, through the diviſions which reigned among the Mahometan princes. In ſuch places as they conquered, they put almoſt every body to the ſword, Chriſtians as well as Mahometans; ſelling their priſoners for ſlaves, and giving up the towns to be plundered by the ſoldiers. From Peluſium they marched to Cairo; which was then in no poſture of defence, and in the utmoſt confuſion, by reaſon of the diviſions which reigned in it. Shawer, therefore, as ſoon as he heard of their approach, cauſed the ancient quarter called *Meſr* to be ſet on fire, and the inhabitants to retire into the other parts. He alſo prevailed upon the caliph to ſolicit the aſſiſtance of Nuroddin; which the latter was indeed pretty much inclined of himſelf to grant, as it gave him the faireſt opportunity he could have wiſhed for, both of driving the cruſaders out of Egypt, and of ſeizing the kingdom to himſelf. For this purpoſe he had already raiſed an army of 60,000 horſe under his general Aſadoddin; and, on the receipt of Al Aded's meſſage, gave them orders to ſet out immediately. The cruſaders were now arrived at Cairo; and had ſo cloſely beſieged that place, that neither Shawer nor the caliph knew any thing of the approach of the Moſlem army which was haſtening to their relief. The vizir, therefore, finding it impoſſible to hold out long againſt the enemy, had recourſe to his old ſubterfuge of treaties and high promiſes. He ſent the enemy 100,000 dinars, and promiſed them 900,000 more, if they would raiſe the ſiege; which they, dreading the approach of Aſadoddin, very readily accepted.

81
They are repulſed by the army of Nuroddin prince of Damaſcus.

The army of Nuroddin now approached the capital by haſty marches, and were everywhere received with the greateſt demonſtrations of joy. Aſadoddin, on his arrival at Cairo, was invited by Al Aded to the royal palace, where he was entertained in the moſt magnificent manner, and received ſeveral preſents; nor were Saladin and the other principal officers leſs magnificently treated. Shawer alſo, conſcious of his perfidious conduct, was no leſs aſſiduous in attending punctually upon him. But having invited the general and ſome others to an entertainment, he had formed a ſcheme of having them ſeized and murdered. The plot, however, being diſcovered, Shawer himſelf had his head cut off, and Aſadoddin was made vizir in his ſtead. He did not, however, long enjoy his new dignity; for he died two months and five days after his inſtalment, being ſucceeded in his office of vizir by his nephew Saladin.

82
Saladin becomes vizir of Egypt.

The new vizir was the youngeſt of all the grandees who aſpired to that office, but had already given ſome ſignal proofs of his valour and conduct. What determined the caliph to prefer him to all the reſt is not known; but it is certain that ſome of them were highly diſpleaſed with his promotion, and even publicly declared that they would not obey him. In order to gain theſe to his intereſt, therefore, Saladin found it neceſſary to diſtribute among them part of the vaſt treaſures left by his uncle; by which means he ſoon governed Egypt without controul, as had been cuſtomary with the vizirs for ſome time before. Soon after his being inſtalled into the office of vizir, he gave a total defeat to the negroes who guarded the royal palace, and had oppoſed his election; by which means, and a ſtrong garriſon he had placed in the caſtle of Cairo, his power became firmly eſtabliſhed. Though he had not the leaſt intention of continuing in his allegiance to Nuroddin, he did not think it prudent at firſt to declare himſelf. He ſent for his father, however, and the reſt of his family, who were in Nuroddin's dominions, in order, as he ſaid, to make them partakers of his grandeur and happineſs. Nuroddin did not think proper to deny this requeſt; though, being already jealous of the great power of Saladin, he inſiſted that his family ſhould conſider him only as one of his generals in Egypt.

A good underſtanding ſubſiſted between Nuroddin and Saladin for ſome time, which did not a little contribute to raiſe the credit of the latter with the Egyptians. In 1169, Nuroddin ſent him orders to omit the name of Al Aded, the caliph of Egypt, in the public prayers, and ſubſtitute that of the caliph of Bagdad in its place. This was at any rate a dangerous attempt; as it might very readily produce a revolt in favour of Al Aded: or if it did not, it gave Saladin an opportunity of engroſſing even that ſmall remnant of power which was left to the caliph. Al Aded, however, was not ſenſible of his diſgrace; for he was on his deathbed, and paſt recovery, when Nuroddin's orders were executed. After his death, Saladin ſeized on all his wealth and valuable effects; which conſiſted of jewels of prodigious ſize, ſumptuous furniture, a library

83
Seizes the effects of the caliph.

containing 100,000 volumes, &c. His family he cauſed to be cloſely confined in the moſt private and retired part of the palace; and either manumitted his ſlaves, or kept them for himſelf, or diſpoſed of them to others.

84 Aſpires to the crown.

Saladin was now arrived at the higheſt pitch of wealth, power, and grandeur. He was, however, obliged to behave with great circumſpection with regard to Nuroddin: who ſtill continued to treat him as his vaſſal, and would not ſuffer him to diſpute the leaſt of his commands. He relied for advice chiefly on his father Ayub; who was a conſummate politician, and very ambitious of ſeeing his ſon raiſed to the throne of Egypt. He therefore adviſed Saladin to continue ſtedfaſt in his reſolutions; and, whilſt he amuſed Nuroddin with feigned ſubmiſſions, to take every method in his power to ſecure himſelf in the poſſeſſion of ſo valuable a kingdom. Nuroddin himſelf, however, was too great a maſter in the art of diſſimulation to be eaſily impoſed on by others; and therefore, though he pretended to be well pleaſed with Saladin's conduct, he was all this time raiſing a powerful army, with which he was fully determined to invade Egypt the following year. But while he meditated this expedition, he was ſeized with a quinſy at the caſtle of Damaſcus, which put an end to his life, in the year 1173.

85 Subdues Arabia Felix.

Saladin, though now freed from the apprehenſions of ſuch a formidable enemy, dared not venture to aſſume the title of *Sovereign*, while he ſaw the ſucceſſor of Nuroddin at the head of a very powerful army, and no leſs deſirous than able to diſpoſſeſs him. For this reaſon his firſt care was to ſecure to himſelf an aſylum, in caſe he ſhould be obliged to leave Egypt altogether. For this purpoſe he choſe the kingdom of Nubia; but having deſpatched his brother Malek Turanſhah thither, at the head of a conſiderable army, the latter was ſo much ſtruck with the ſterility and deſolate appearance of the country, that he returned without attempting any thing. Saladin then ſent his brother into Arabia Felix, in order to ſubdue that country, which had been for ſome time held by Abdalnabi an Arabian prince. Malek entered the country without oppoſition; and having brought Abdalnabi to a general action, entirely defeated him, took him priſoner, and threw him into irons. He then overran and reduced under ſubjection to Saladin great part of the country, taking no fewer than 80 caſtles or fortreſſes of conſiderable ſtrength.

86 Aſſumes the title of ſultan.

After this good fortune, Saladin, now ſure of a convenient place of refuge in caſe of any misfortune, aſſumed the title of *Sultan* or ſovereign of Egypt; and was acknowledged as ſuch by the greater part of the ſtates. The zeal of the Egyptians for the Fatemite caliphs, however, ſoon produced a rebellion. One *Al Kanz*, or *Kanzanaddowla*, governor of a city in Upper Egypt, aſſembled a great army of blacks, or rather ſwarthy natives; and marching directly into the lower country, was there joined by great numbers of other Egyptians. Againſt them Saladin deſpatched his brother Malek, who ſoon defeated and entirely diſperſed them. This, however, did not prevent another inſurrection under an impoſtor, who pretended to be David the ſon of Al Aded the laſt Fatemite caliph, and had collected a body of 100,000 men. But before theſe had time to do any great damage, they were ſurpriſed by the ſultan's forces, and entirely defeated. Above 300 were publicly hanged, and a vaſt number periſhed in the field, inſomuch that it was thought ſcarce a fourth part of the whole body eſcaped.

About this time Saladin gained a conſiderable advantage over the cruſaders, commanded by William II. king of Sicily. That prince had invaded Egypt with a numerous fleet and army, with which he laid cloſe ſiege to Alexandria both by ſea and land. Saladin, however, marched to the relief of the city with ſuch ſurpriſing expedition, that the cruſaders were ſeized with a ſudden panic, and fled with the utmoſt precipitation, leaving all their military engines, ſtores, and baggage behind.

87 Saladin made ſovereign of Damaſcus.

In the year 1175, the inhabitants of Damaſcus begged of Saladin to accept the ſovereignty of that city and its dependencies; being jealous of the miniſter, who had the tuition of the reigning prince, and who governed all with an abſolute ſway. The application was no ſooner made, than the ſultan ſet out with the utmoſt celerity to Damaſcus, at the head of a choſen detachment of 700 horſe. Having ſettled his affairs in that city, he appointed his brother Saif Al Iſlam governor of it; and ſet out for Hems, to which he immediately laid ſiege. Having made himſelf maſter of this place, he then proceeded to Hamah. The city very ſoon ſurrendered, but the citadel held out for ſome time. Saladin pretended that he accepted the ſovereignty of Damaſcus and the other places he had conquered, only as deputy to Al Malek Al Saleh, the ſucceſſor of Nuroddin, and who was then under age; and that he was deſirous of ſending Azzoddin, who commanded in the citadel, with a letter to Aleppo, where the young prince reſided. This ſo pleaſed Azzoddin, that he took the oath of fidelity to Saladin, and immediately ſet out with the ſultan's letter. He had not, however, been long at Aleppo before he was by the miniſter's orders thrown into priſon; upon which his brother, who had been appointed governor of the citadel Hamah in his abſence, delivered it up to Saladin without further ceremony. The ſultan then marched to Aleppo, with a deſign to reduce it; but, being vigorouſly repulſed in ſeveral attacks, he was at laſt obliged to abandon the enterpriſe. At the ſame time, Kamſchlegin, Al Malek's miniſter or vizir, hired the chief of the Bataniſts, or Aſſaſſins *, to murder him. Several attempts were made in conſequence of this application; but all of them, happily for Saladin, miſcarried.

88 Defeats his enemies.

After raiſing the ſiege of Aleppo, Saladin returned to Hems, which place the cruſaders had inveſted. On his approach, however, they thought proper to retire; after which, the ſultan made himſelf maſter of the ſtrong caſtle belonging to that place, which before he had not been able to reduce. This was ſoon followed by the reduction of Baalbec: and theſe rapid conqueſts ſo alarmed the miniſters of Al Malek, that, entering into a combination with ſome of the neighbouring princes, they raiſed a formidable army, with which they deſigned to cruſh the ſultan at once. Saladin, fearing the event of a war, offered to cede Hems and Hamah to Al Malek, and govern Damaſcus only as his lieutenant: but theſe terms being rejected, a battle enſued; in which the allied army was utterly defeated, and the ſhattered remains of it ſhut up in the city of Aleppo. This produced a treaty, by which

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* See *Aſſaſſin*.

Saladin was left maſter of all Syria, excepting only the city of Aleppo and the territory belonging to it.

89 Receives a terrible overthrow from the cruſaders.

In 1176 Saladin returned from the conqueſt of Syria, and made his triumphal entry into Cairo. Here, having reſted himſelf and his troops for ſome time, he began to encompaſs the city with a wall 29,000 cubits in length, but which he did not live to finiſh. Next year he led a very numerous army into Paleſtine againſt the cruſaders. But here his uſual good fortune failed him. His army was entirely defeated. Forty thouſand of his men were left dead on the field; and the reſt fled with ſo much precipitation, that, having no towns in the neighbourhood where they could ſhelter themſelves, they traverſed the vaſt deſert between Paleſtine and Egypt, and ſcarce ſtopped till they reached the capital itſelf. The greateſt part of the army by this means periſhed; and as no water was to be had in the deſert above mentioned, almoſt all the beaſts died of thirſt before the fugitives arrived on the confines of Egypt. Saladin himſelf ſeemed to have been greatly intimidated; for in a letter to his brother Al Malek, he told him, that "he was more than once in the moſt imminent danger; and that God, as he apprehended, had delivered him from thence, in order to reſerve him for the execution of ſome grand and important deſign."

In the year 1182, the ſultan ſet out on an expedition to Syria with a formidable army, amidſt the acclamations and good wiſhes of the people. He was, however, repulſed with loſs both before Aleppo and Al Mawſel, after having ſpent much time and labour in beſieging theſe two important places.

90 The Chriſtians receive a great defeat at ſea.

In the mean time, a moſt powerful fleet of European ſhips appeared on the Red ſea, which threatened the cities of Mecca and Medina with the utmoſt danger. The news of this armament no ſooner reached Cairo, than Abu Becr, Saladin's brother, who had been left viceroy in the ſultan's abſence, cauſed another to be fitted out with all ſpeed under the command of Lulu, a brave and experienced officer, who quickly came up with them, and a dreadful engagement enſued. The Chriſtians were defeated after an obſtinate reſiſtance, and all the priſoners butchered in cold blood. This proved ſuch a terrible blow to the Europeans, that they never more ventured on a like attempt.

91 Saladin's rapid conqueſts.

In 1183, Saladin continued to extend his conqueſts. The city of Amida in Meſopotamia ſurrendered to him in eight days; after which, being provoked by ſome violences committed by the prince of Aleppo, he reſolved at all events to make himſelf maſter of that place. He was now attended with better ſucceſs than formerly; for as his army was very numerous, and he puſhed on the ſiege with the utmoſt vigour, Amadoddin the prince capitulated, upon condition of being allowed to poſſeſs certain cities in Meſopotamia which had formerly belonged to him, and being ready to attend the ſultan on whatever expedition he pleaſed. After the conqueſt of Aleppo, Saladin took three other cities, and then marched againſt his old enemies the cruſaders. Having ſent out a party to reconnoitre the enemy, they fell in with a conſiderable detachment of Chriſtians; whom they eaſily defeated, taking about 100 priſoners, with the loſs of only a ſingle man on their ſide. The ſultan, animated by this firſt inſtance of ſucceſs, drew up his forces in order of battle, and advanced againſt the cruſaders, who had aſſembled their whole army at Sepphoris in Galilee. On viewing the ſultan's troops, however, and perceiving them to be greatly ſuperior in ſtrength to what they had at firſt apprehended, they thought proper to decline an engagement, nor could Saladin with all his ſkill force them to it. But though it was found impoſſible to bring the cruſaders to a deciſive engagement, Saladin found means to haraſs them greatly, and deſtroyed great numbers of their men. He carried off alſo many priſoners, diſmantled three of their ſtrongeſt cities, laid waſte their territories, and concluded the campaign with taking another ſtrong town.

92 Chriſtians totally defeated.

For three years Saladin continued to gain ground on the cruſaders, yet without any deciſive advantage; but in 1187, the fortune of war was remarkably unfavourable to them. The Chriſtians now found themſelves obliged to venture a battle, by reaſon of the cruel ravages committed in their territories by Saladin, and by reaſon of the encroachments he daily made on them. Both armies therefore being reſolved to exert their utmoſt efforts, a moſt fierce and bloody battle enſued. Night prevented victory from declaring on either ſide, and the fight was renewed with equal obſtinacy next day. The victory was ſtill left undecided; but the third day the ſultan's men finding themſelves ſurrounded by the enemy on all ſides but one, and there alſo hemmed in by the river Jordan, ſo that there was no room to fly, fought like men in deſpair, and at laſt gained a moſt complete victory. Vaſt numbers of the Chriſtians periſhed on the field. A large body found means to retire in ſafety to the top of a neighbouring hill covered with wood; but being ſurrounded by Saladin's troops, who ſet fire to the wood, they were all obliged to ſurrender at diſcretion. Some of them were butchered by their enemies as ſoon as they delivered themſelves into their hands, and others thrown into irons. Among the latter were the king of Jeruſalem himſelf, Arnold prince of Al Shawbec and Al Carac, the maſters of the Templars and Hoſpitalers, with almoſt the whole body of the latter. So great was the conſternation of the Chriſtians on this occaſion, that one of Saladin's men is ſaid to have taken 30 of them priſoners, and tied them together with the cord of his tent, to prevent them from making their eſcape. The maſters of the Templars and Hoſpitalers, with the knights acting under them, were no ſooner brought into Saladin's preſence, than he ordered them all to be cut in pieces. He called them *Aſſaſſins* or *Bataniſts*; and had been wont to pay 50 dinars for the head of every Templar or Hoſpitaler that was brought him. After the engagement, Saladin ſeated himſelf in a magnificent tent, placing the king of Jeruſalem on his right hand, and Arnold prince of Al Shawbec and Al Carac on his left. Then he drank to the former, who was at that time ready to expire with thirſt, and at the ſame time offered him a cup of ſnow water. This was thankfully received; and the king immediately drank to the prince of Al Carac, who ſat near him. But here Saladin interrupted him with ſome warmth: "I will not (ſays he) ſuffer this curſed rogue to drink; as that, according to the laudable and generous cuſtom of the Arabs, would ſecure to him his life." Then, turning

turning towards the prince, he reproached him with having undertaken the expedition while in alliance with himſelf, with having intercepted an Egyptian caravan in the time of profound peace, and maſſacring the people of which it was compoſed, &c. Notwithſtanding all this, he told him, he would grant him his life, if he would embrace Mahometaniſm. This condition, however, was refuſed; and the ſultan, with one ſtroke of his ſcimitar, cut off the prince's head. This greatly terrified the king of Jeruſalem; but Saladin aſſured him he had nothing to fear, and that Arnold had brought on himſelf a violent death by his want of common honeſty.

93
His further conqueſts.

The cruſaders being thus totally defeated and diſperſed, Saladin next laid ſiege to Tiberias, which capitulated in a ſhort time. From thence he marched towards Acca or Ptolemais, which likewiſe ſurrendered after a ſhort ſiege. Here he found 4000 Mahometan priſoners in chains, whom he immediately releaſed. As the inhabitants enjoyed at preſent a very extenſive trade, the place being full of merchants, he found there not only vaſt ſums of money, but likewiſe a great variety of wares exceedingly valuable, all which he ſeized and applied to his own uſe. About the ſame time his brother Al Malec attacked and took a very ſtrong fortreſs in the neighbourhood; after which the ſultan divided his army into three bodies, that he might with the greater facility overrun the territories of the Chriſtians. Thus, in a very ſhort time, he made himſelf maſter of Neapolis, Cæſarea, Sepphoris, and other cities in the neighbourhood of Ptolemais, where his ſoldiers found only women and children, the men having been all killed or taken priſoners. His next conqueſt was Joppa, which was taken by ſtorm after a vigorous reſiſtance. Every thing being then ſettled, and a diſtribution made of the ſpoils and captives, Saladin marched in perſon againſt Tebrien, a ſtrong fortreſs in the neighbourhood of Sidon; which was taken by aſſault, after it had ſuſtained a ſiege of ſix days. No ſooner was he maſter of this place, than he ordered the fortreſs to be razed, and the garriſon put to the ſword. From Tebrien the victorious ſultan proceeded to Sidon itſelf; which, being deſerted by its prince, ſurrendered almoſt on the firſt ſummons. Berytus was next inveſted, and ſurrendered in ſeven days. Among the priſoners Saladin found in this place the prince of a territory called *Hobeil*, who by way of ranſom delivered up his dominions to him, and was of conſequence releaſed. About the ſame time, a Chriſtian ſhip, in which was a nobleman of great courage and experience in war, arrived at the harbour of Ptolemais, not knowing that it was in the hands of Saladin. The governor might eaſily have ſecured the veſſel; but neglecting the opportunity, ſhe eſcaped to Tyre, where the above-mentioned nobleman, together with the prince of Hobeil, contributed not a little to retrieve the affairs of the Chriſtians, and enable them to make a ſtand for four years after.

94
Jeruſalem taken.

Saladin in the mean time went on with his conqueſts. Having made himſelf maſter of Aſcalon after a ſiege of 14 days, he next inveſted Jeruſalem. The garriſon was numerous, and made an obſtinate defence; but Saladin having at laſt made a breach in the walls by ſapping, the beſieged deſired to capitulate. This was at firſt refuſed: upon which the Chriſtian ambaſſador made the following ſpeech: "If that be the caſe, know, O ſultan, that we who are extremely numerous, and have been reſtrained from fighting like men in deſpair only by the hopes of an honourable capitulation, will kill all our wives and children, commit all our wealth and valuable effects to the flames, maſſacre 5000 priſoners now in our hands, leave not a ſingle beaſt of burden or animal of any kind belonging to us alive, and level with the ground the rock you eſteem ſacred, together with the temple Al Akſa. After this we will ſally out upon you in a body; and doubt not but we ſhall either cut to pieces a much greater number of you than we are, or force you to abandon the ſiege." This deſperate ſpeech had ſuch an effect upon Saladin, that he immediately called a council of war, at which all the general officers declared, that it would be moſt proper to allow the Chriſtians to depart unmoleſted. The ſultan therefore allowed them to march out freely and ſecurely with their wives, children, and effects; after which he received ten dinars from every man capable of paying that ſum, five from every woman, and two from every young perſon under age. For the poor who were not able to pay any thing, the reſt of the inhabitants raiſed the ſum of 30,000 dinars.

Moſt of the inhabitants of Jeruſalem were eſcorted by a detachment of Saladin's troops to Tyre; and ſoon after, he advanced with his army againſt that place. As the port was blocked up by a ſquadron of five men of war, Saladin imagined that he ſhould eaſily become maſter of it. But in this he found himſelf miſtaken. For, one morning by break of day, a Chriſtian fleet fell upon his ſquadron, and entirely defeated it; nor did a ſingle veſſel eſcape their purſuit. A conſiderable number of the Mahometans threw themſelves into the ſea during the engagement; moſt of whom were drowned, though ſome few eſcaped. About the ſame time Saladin himſelf was vigorouſly repulſed by land; ſo that, after calling a council of war, it was thought proper to raiſe the ſiege.

In 1188, Saladin, though his conqueſts were not ſo rapid and conſiderable as hitherto, continued ſtill ſuperior to his enemies. He reduced the city of Laodicea and ſome others, together with many ſtrong caſtles; but met alſo with ſeveral repulſes. At laſt he took the road to Antioch; and having reduced all the fortreſſes that lay in his way, many of which had been deemed impregnable, Bohemond prince of Antioch was ſo much intimidated, that he deſired a truce for ſeven or eight months. This Saladin found himſelf obliged to comply with, on account of the prodigious fatigues his men had ſuſtained, and becauſe his auxiliaries now demanded leave to return home.

95
Cruſaders retrieve their affairs.

All theſe heavy loſſes of the Chriſtians, however, proved in ſome reſpects an advantage, as they were thus obliged to lay aſide their animoſities, which had originally proved the ruin of their affairs. Thoſe who had defended Jeruſalem, and moſt of the other fortreſſes taken by Saladin, having retreated to Tyre, formed there a very numerous body. This proved the means of preſerving that city, and alſo of re-eſtabliſhing their affairs for the preſent. For, having received powerful ſuccours from Europe, they were enabled in 1189 to take the field with 30,000 foot and 2000 horſe. Their firſt attempt was upon Alexandretta; from whence they diſlodged a ſtrong party of Mahometans, and made themſelves maſters of the place with very little loſs. They next laid ſiege to Ptolemais; of which Saladin had no ſooner received intelligence, than he marched to the relief of the place. After ſeveral ſkirmiſhes with various ſucceſs, a general engagement enſued, in which Saladin was defeated with the loſs of 10,000 men. This enabled the Chriſtians to carry on the ſiege of Ptolemais with greater vigour; which place, however, they were not able to reduce for the ſpace of two years.

This year the ſultan was greatly alarmed by an account that the emperor of Germany was advancing to Conſtantinople with an army of 260,000 men, in order to aſſiſt the other cruſaders. This prodigious armament, however, came to nothing. The multitude was ſo reduced with ſickneſs, famine, and fatigue, that ſcarce 1000 of them reached the camp before Ptolemais. The ſiege of that city was continued, though with bad ſucceſs on the part of the Chriſtians. They were repulſed in all their attacks, their engines were burnt with naphtha, and the beſieged always received ſupplies of proviſions in ſpite of the utmoſt efforts of the beſiegers; at the ſame time that a dreadful famine and peſtilence raged in the Chriſtian camp, which ſometimes carried off 200 people a-day.

96
Richard I. of England arrives in Aſia.

In 1191, the Chriſtians received powerful ſuccours from Europe. Philip II. of France, and Richard I. of England (from his great courage ſurnamed *Cœur de Lion)* arrived at the camp before Ptolemais. The latter was eſteemed the braveſt and moſt enterpriſing of all the generals the cruſaders had; and the ſpirits of his ſoldiers were greatly elated by the thoughts of acting under ſuch an experienced commander. Soon after his arrival, the Engliſh ſunk a Mahometan ſhip of vaſt ſize, having on board 650 ſoldiers, a great quantity of arms and proviſions, going from Berytus to Ptolemais. Of the ſoldiers and ſailors who navigated this veſſel, only a ſingle perſon eſcaped; who being taken priſoner by the Engliſh, was deſpatched to the ſultan with the news of the diſaſter. The beſieged ſtill defended themſelves with the greateſt reſolution; and the king of England happening to fall ſick, the operations of the beſiegers were conſiderably delayed. On his recovery, however, the attacks were renewed with ſuch fury, that the place was every moment in danger of being taken by aſſault. This induced them to ſend a letter to Saladin, informing him, that if they did not receive ſuccours the very next day, they would be obliged to ſubmit. As this town was the ſultan's principal magazine of arms, he was greatly affected with the account of their diſtreſs, eſpecially as he found it impoſſible to relieve them. The inhabitants, therefore, found themſelves under a neceſſity of ſurrendering the place. One of the terms of the capitulation was, that the cruſaders ſhould receive a very conſiderable ſum of money from Saladin, in conſequence of their delivering up the Mahometan priſoners they had in their hands. This article Saladin refuſed to comply with; and, in conſequence of his refuſal, Richard cauſed 3000 of thoſe unfortunate men to be ſlaughtered at once.

97
Defeats Saladin.

After the reduction of Ptolemais, the king of England, now made generaliſſimo of the cruſaders, took the road to Aſcalon, in order to beſiege that place; after which, he intended to make an attempt upon Jeruſalem itſelf. Saladin propoſed to intercept his paſſage, and placed himſelf in the way with an army of 300,000 men. On this occaſion was fought one of the greateſt battles of that age. Saladin was totally defeated, with the loſs of 40,000 men; and Aſcalon ſoon fell into the hands of the cruſaders. Other ſieges were afterwards carried on with ſucceſs, and Richard even approached within ſight of Jeruſalem, when he found, that by reaſon of the weakened ſtate of his army, and the diviſions which prevailed among the officers who commanded it, he ſhould be under the neceſſity of concluding a truce with the ſultan. This was accordingly done in the year 1192; the term was, three years, three months, three weeks, three days, and three hours; ſoon after which the king of England ſet out on his return to his own dominions.

98
Mamlouks become maſters of Egypt.

99
Account of them.

In 1193 Saladin died, to the inexpreſſible grief of all true Mahometans, who held him in the utmoſt veneration. His dominions in Syria and Paleſtine were ſhared out among his children and relations into many petty principalities. His ſon Othman ſucceeded to the crown of Egypt: but as none of his ſucceſſors poſſeſſed the enterpriſing genius of Saladin, the hiſtory from that time till the year 1250 affords nothing remarkable. At this time the reigning ſultan Malek Al Salek was dethroned and ſlain by the *Mamelucs* or *Mamlouks*, as they are called, a kind of mercenary ſoldiers who ſerved under him. In conſequence of this revolution, the Mamlouks became maſters of Egypt, and choſe a ſultan from among themſelves.—Theſe Mamlouks are thought to have been young Turks or Tartars, ſold to private perſons by the merchants, from whom they were bought by the ſultan, educated at his expence, and employed to defend the maritime places of the kingdom. The reaſon of this inſtitution originally was, that the native Egyptians were become ſo cowardly, treacherous, and effeminate, from a long courſe of ſlavery, that they were unfit for arms. The Mamlouks, on the contrary, made moſt excellent ſoldiers; for having no friends but amongſt their own corps, they turned all their thoughts to their own profeſſion. According to M. Volney, they came originally from Mount Caucaſus, and are diſtinguiſhed by the flaxen colour of their hair. Here they were found by the cruſaders, and were by them called *Mamelucs*, or more correctly *Mamlouks*. The expedition of the Tartars in in 1227 proved indirectly the means of introducing them into Egypt. Theſe horrible conquerors, having ſlaughtered and maſſacred till they were weary, brought along with them an immenſe number of ſlaves of both ſexes, with whom they filled all the markets in Aſia. The Turks, taking advantage of the opportunity, purchaſed about 12,000 young men, whom they bred up in the profeſſion of arms, in which they ſoon attained to great perfection; but becoming mutinous, like the Roman pretorian bands, they turned their arms againſt their maſters, and in 1250 depoſed and murdered the caliph, as has been already related.

The Mamlouks having got poſſeſſion of the government, and neither underſtanding nor putting a value upon any thing beſides the art of war, every ſpecies of learning decayed in Egypt, and a great degree of barbariſm was introduced. Neither was their empire of long duration notwithſtanding all their martial abilities. The reaſon of this was, that they were originally only a ſmall part of the ſultan of Egypt's ſtanding forces. As a numerous ſtanding army was neceſſary in a country where the fundamental maxim of government was, that every native muſt be a ſlave, they were at firſt at a loſs how to act; being juſtly ſuſpicious of all the reſt of the army. At laſt they reſolved to buy Chriſtian ſlaves, and educate them in the ſame way that they themſelves had formerly been. Theſe were commonly brought from Circaſſia, where the people, though they profeſſed Chriſtianity, made no ſcruple of ſelling their children. When they were completed in their military education, theſe ſoldiers were diſpoſed of through all the fortreſſes erected in the country to bridle the inhabitants; and becauſe in their language ſuch a fort was called *Borge*, the new militia obtained the name of *Borgites*. By this expedient the Mamlouks imagined they would be able to ſecure themſelves in the ſovereignty. But in this they were miſtaken.

100 Driven out by the Borgites.

In proceſs of time, the old Mamlouks grew proud, inſolent, and lazy: and the Borgites, taking advantage of this, roſe upon their maſters, deprived them of the government, and transferred it to themſelves about the year 1382.

The Borgites, as well as the former, aſſumed the name of *Mamlouks;* and were famous for their valour and ferocity of conduct. They were almoſt perpetually engaged in wars either foreign or domeſtic; and their dominion laſted till the year 1517, when they were

101 Egypt conquered by Selim.

invaded by Selim the Turkiſh ſultan. The Mamlouks defended themſelves with incredible valour; notwithſtanding which, being overpowered by numbers, they were defeated in every engagement. The ſame year, their capital, the city of Cairo, was taken, with a terrible ſlaughter of thoſe who defended it. The ſultan was forced to fly; and, having collected all his force ventured a deciſive battle. The moſt romantic efforts of valour, however, were inſufficient to cope with the innumerable multitude which compoſed the Turkiſh army. Moſt of his men were cut in pieces, and the unhappy prince himſelf was at laſt obliged to take ſhelter in a marſh. He was dragged from his hiding-place, where he had ſtood up to the ſhoulders in water, and ſoon after put to death. With him ended the glory, and almoſt the exiſtence, of the Mamlouks, who were now everywhere ſearched for and cut in pieces.

This was the laſt great revolution in the Egyptian affairs: a revolution very little to the advantage of the natives, who may well doubt whether their ancient or modern conquerors have behaved with the greater degree of barbarity. Selim gave a ſpecimen of his government, the very day after his being put in full poſſeſſion of it, by the death of Tuman Bey the unfortunate

102 His horrid cruelty.

ſultan above mentioned. Having ordered a theatre to be erected with a throne upon it on the banks of the Nile, he cauſed all the priſoners, upwards of 30,000 in number, to be beheaded in his preſence, and their bodies thrown into the river.

Notwithſtanding this horrid cruelty of Selim, he did not attempt the total extermination of the race of Mamlouks, though this would have been quite agreeable to the maxims of Turkiſh policy; but in the preſent caſe he ſeems to have recollected, that if he eſtabliſhed a pacha in Egypt with the ſame powers with which he inveſted thoſe of other parts, he would be under ſtrong temptations to revolt by reaſon of the diſtance from the capital.

103 New form of government introduced by Selim.

He therefore propoſed a new form of government, by which the power being diſtributed among the different members of the ſtate, ſhould preſerve an equilibrium, ſo that the dependence of the whole ſhould be upon himſelf. With this view, he choſe from among the Mamlouks who had eſcaped the general maſſacre, a divan, or council of regency, conſiſting of the pacha and chiefs of the ſeven military corps. The former was to notify to this council the orders of the Porte, to ſend the tribute to Conſtantinople, and provide for the ſafety of government both external and internal; while, on the other hand, the members of the council had a right to reject the orders of the pacha, or even of depoſing him, provided they could aſſign ſufficient reaſons. All civil and political ordinances muſt alſo be ratified by them. Beſides this, he formed the whole body into a

104 His edict for a republic.

republic; for which purpoſe he iſſued an edict to the following purpoſe: "Though, by the help of the Almighty, we have conquered the whole kingdom of Egypt with our invincible armies; nevertheleſs our benevolence is willing to grant to the 24 ſangiacs (A) of Egypt a republican government, with the following conditions.

"I. That our ſovereignty ſhall be acknowledged by the republic; and in token of their obedience, our lieutenant ſhall be received as our repreſentative: but to do nothing againſt our will or the republic; but, on the contrary, ſhall co-operate with it for its welfare on all occaſions. Or if he ſhall attempt to infringe any of its privileges, the republic is at liberty to ſuſpend him from his authority, and to ſend to our Sublime Porte a complaint againſt him, &c.

"II. In time of war, the republic ſhall provide 12,000 troops at its own expence, to be commanded by a ſangiac or ſangiacs.

"III. The republic ſhall raiſe annually and ſend to our Sublime Porte the ſum of 560,000 aſlany (B), accompanied by a ſangiac, who ſhall have a ſatisfactory receipt, &c.

"IV. The ſame ſum to be raiſed for the uſe of Medina, and Kiabe or Mecca.

"V. No more troops of Janizaries ſhall be kept by the republic in time of peace than 14,000; but in time of war they may be increaſed to oppoſe our and the republic's enemies.

"VI. The republic ſhall ſend annually to our granary, out of the produce of the country, one million of caſiz (C) or meaſures of corn, viz. 600,000 of wheat and 400,000 of barley.

"VII. The republic, fulfilling theſe articles, ſhall have a free government over all the inhabitants of Egypt,

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(A) Theſe ſangiacs are the governors of provinces.

(B) Each of theſe coins is in value about half-a-crown Engliſh; and the tribute ſince that time has been augmented to 800,000 aſlany, or about 100,000l. ſterling.

(C) Each caſiz weighs 25 occa, and each occa is equal to two pounds ten ounces Engliſh avoirdupois weight.

gypt, independent of our lieutenant, but ſhall execute the laws of the country with the advice of the mollah or high prieſt under our authority and that of our ſucceſſors.

"VIII. The republic ſhall be in poſſeſſion of the mint as heretofore; but with this condition, that it ſhall be under the inſpection of our lieutenant, that the coin may not be adulterated.

"IX. That the republic ſhall elect a *ſheik bellet* out of the number of beys, to be confirmed by our lieutenant; and that the ſaid ſheik bellet ſhall be our repreſentative, and ſhall be eſteemed by all our lieutenants, and all our officers both of high and low rank, as the head of the republic; and if our lieutenant is guilty of oppreſſion, or exceeds the bounds of his authority, the ſaid ſheik bellet ſhall repreſent the grievances of the republic to our Sublime Porte: but in caſe any foreign enemy or enemies diſturb the peace of the republic, we and our ſucceſſors engage to protect it with our utmoſt power until peace is re-eſtabliſhed, without any coſt or expence to the republic.

"Given and ſigned by our *clemency* to the republic of Egypt."

105
The Turkiſh power now almoſt entirely loſt.

106
Why the children of the Mamlouks and Turks all die in Egypt.

Thus the power of the Mamlouks ſtill continued in a very conſiderable degree, and by degrees increaſed ſo much as to threaten a total loſs of dominion to the Turks. During the laſt 50 years, the Porte having relaxed from its vigilance, ſuch a revolution has taken place, that the Turkiſh power is now almoſt reduced to nothing. But in order to underſtand this, we muſt conſider the way in which the race of Mamlouks is continued or multiplied in Egypt. This is not in the ordinary way, by marriage. on the contrary, M. Volney aſſures us, that "during 350 years in which there have been Mamlouks in Egypt, not one of them has left ſubſiſting iſſue; all their children periſh in the firſt or ſecond deſcent. Almoſt the ſame thing holds good with regard to the Turks; and it is obſerved, that they can only ſecure the continuance of their families by marrying women who are natives, which the Mamlouks have always diſdained. The means by which they are perpetuated and multiplied are the ſame by which they were firſt eſtabliſhed, viz. by ſlaves brought from their original country. From the time of the Moguls this commerce has been continued on the banks of the Cuban and Phaſis in the ſame manner as it is carried on in Africa, by the wars among the hoſtile tribes, and the miſery or avarice of the inhabitants, who ſell their children to ſtrangers. The ſlaves thus procured are firſt brought to Conſtantinople, and afterwards diſperſed through the empire, where they are purchaſed by the wealthy. When the Turks ſubdued Egypt (ſays M. Volney), they ſhould undoubtedly have prohibited this dangerous traffic; their omitting which ſeems about to diſpoſſeſs them of their conqueſt, and which ſeveral political errors have long been preparing.

107
Authority uſurped by Ibrahim Kiaya.

"For a conſiderable time the Porte had neglected the affairs of this province; and in order to reſtrain the pachas, had ſuffered the divan to extend its power till the chiefs of the janizaries and azabs were left without controul. The ſoldiers themſelves, become citizens by the marriages they had contracted, were no longer the creatures of Conſtantinople; and a change introduced into their diſcipline ſtill more increaſed theſe diſorders. At firſt the ſeven military corps had one common treaſury; and though the ſociety was rich, individuals, not having any thing at their own diſpoſal, could effect nothing. The chiefs, finding their power diminiſhed by this regulation, had intereſt enough to get it aboliſhed, and obtained permiſſion to poſſeſs diſtinct property, lands, and villages. And as theſe lands and villages depended on the Mamlouk governors, it was neceſſary to conciliate them, to prevent their oppreſſions. From that moment the beys acquired an aſcendancy over the ſoldiers, who till then had treated them with diſdain; and this could not but continually increaſe, ſince their governments procured them conſiderable riches. Theſe they employed in creating themſelves friends and creatures. They multiplied their ſlaves; and after emancipating them, employed all their intereſt to promote them to various employments, and advance them in the army. Theſe upſtarts, retaining for their patrons the ſame ſuperſtitious veneration common in the Eaſt, formed factions implicitly devoted to their pleaſure." Thus, about the year 1746, Ibrahim, one of the kiayas (D) of the janizaries, rendered himſelf in reality maſter of Egypt; having managed matters ſo well, that of the 24 beys or ſangiacs eight were of his houſehold. His influence too was augmented by always leaving vacancies in order to enjoy the emoluments himſelf; while the officers and ſoldiers of his corps were attached to his intereſt: and his power was completed by gaining over Rodoan, the moſt powerful of all the colonels, to his intereſt. Thus the pacha became altogether unable to oppoſe him, and the orders of the ſultan were leſs reſpected than thoſe of Ibrahim. On his death in 1757, his family, i. e. his enfranchiſed ſlaves, continued to rule in a deſpotic manner. Waging war, however, among each other, Rodoan, and ſeveral other chiefs were killed; until, in 1766, Ali Bey, who had been a principal actor in the diſturbances, overcame his enemies, and for ſome time rendered himſelf abſolute maſter of Egypt.

108
Hiſtory of Ali Bey.

109
He is bought and educated by Ibrahim Kiaya.

Of this man there are various accounts. The following is that given by M. Volney. He begins with obſerving, that the private hiſtory of the Mamlouks in general muſt be ſubject to great uncertainty, by reaſon of their being generally carried off from their parents at a time of life when they can remember but little or nothing of their parents; and he remarks, that they are likewiſe unwilling to communicate the little they may happen to remember. It is moſt commonly ſuppoſed, however, that Ali Bey was born among the Abazans, a people of Mount Caucaſus; from whom, next to the Circaſſians, the ſlaves moſt valued by the Turks, and other nations who deal in that commodity, are to be obtained. Having been brought to a public ſale at Cairo, Ali Bey was bought by two Jew brothers named Iſaac and Youſef, who made a preſent of him to Ibrahim Kiaya.

(D) Theſe were the commanding officers of the janizaries, azabs, &c. who after the firſt year laid down their employments, and became veterans, with a voice in the divan.

Kiaya. At this time he is ſuppoſed to have been about 13 or 14 years old, and was employed by his patron in offices ſimilar to thoſe of the pages belonging to European princes. The uſual education was alſo given him ; viz. that of learning to manage a horſe well; fire a carabine and piſtol ; throw the djerid, a kind of dart uſed in the diverſions of that country, and which ſhall be afterwards deſcribed. He was alſo taught the exerciſe of the ſabre, and a little reading and writing. In all the feats of activity juſt mentioned, he diſcovered ſuch impetuoſity, that he obtained the ſurname of *Djendali*, or "madman ;" and as he grew up, diſcovered an ambition proportionable to the activity diſplayed in his youth. About the age of 18 or 20, his patron gave him his freedom ; the badge of which among the Turks is the letting the beard grow, for among that people it is thought proper only for women and ſlaves to want a beard. By his kind patron alſo he was promoted to the rank of kachef or governor of a diſtrict, and at laſt elected one of the 24 beys. By the death of Ibrahim in 1757, he had an opportunity of ſatisfying his ambition ; and now engaged in every ſcheme for the promotion or diſgrace of the chiefs, and had a principal ſhare in the ruin of Rodoan Kiaya above mentioned. Rodoan's place was quickly filled by another, who did not long enjoy it ; and in 1762 Ali Bey, then ſtyled *Sheik-el-Beled*, having got Abdelrahman, the poſſeſſor at that time, exiled, procured himſelf to be elected in his room.

110 He is baniſhed, but returns, and throws off the Turkiſh yoke.

However, he ſoon ſhared the fate of the reſt, being condemned to retire to Gaza. This place, being under the dominion of a Turkiſh pacha, was by no means agreeable ; for which reaſon Ali having turned off to another place, kept himſelf concealed for ſome time, until in 1766 his friends at Cairo procured his recal. On this he appeared ſuddenly in that city ; and in one night killed four of the beys who were inimical to his deſigns, baniſhed the reſt, and aſſumed the whole power to himſelf. Still, however, his ambition was not ſatisfied ; and he determined on nothing leſs then to throw off his dependence on the Porte altogether, and become ſultan of Egypt. With this view he expelled the pacha, refuſed to pay the accuſtomed tribute, and in the year 1768 proceeded to coin money in his own name. The Porte being at that time on the eve of a dangerous war with Ruſſia, had not leiſure to attend to the proceedings of Ali Bey ; ſo that the latter had an opportunity of going forward with his enterpriſes very vigorouſly.

111 Overcomes an Arabian prince.

His firſt expedition was againſt an Arabian prince named *Hammam ;* againſt whom he ſent his favourite Mohammed Bey, under pretence that the former had concealed a treaſure intruſted with him by Ibrahim Kiaya, and that he afforded protection to rebels.

112 Propoſes to make Mecca the emporium of Eaſt Indian commerce.

Having deſtroyed this unfortunate prince, he next began to put in execution a plan propoſed to him by a young Venetian merchant, of rendering Jedda, the port of Mecca, an emporium for all the commerce of India ; and even imagined he ſhould be able to make the Europeans abandon the paſſage to the Indies by the Cape of Good Hope. With this view, he fitted out ſome veſſels at Suez ; and manning them with Mamlouks, commanded the bey Haſſan to ſail with them to Jedda, and ſeize upon it, while a body of cavalry under Mohammed Bey advanced againſt the town. Both theſe commiſſions were executed according to his wiſh, and Ali became quite intoxicated with his ſucceſs. Nothing but ideas of conqueſt now occupied his mind, without conſidering the immenſe diſproportion between his own force and that of the grand ſignior. Circumſtances, it muſt be owned, were at that time very favourable to his ſchemes. The ſheik Daher was in rebellion againſt the Porte in Syria ; and the pacha of Damaſcus had ſo exaſperated the people by his extortions, that they were ready for a revolt.

113 His expedition into Syria.

Having therefore made the neceſſary preparations, Ali Bey deſpatched in 1770 about 500 Mamlouks to take poſſeſſion of Gaza, and thus ſecure an entrance into Paleſtine. Oſman, the pacha of Damaſcus, however, no ſooner heard of the invaſion than he prepared for war with the utmoſt diligence, while the troops of Ali Bey held themſelves in readineſs to fly on the firſt attack. They were relieved from their embarraſſment by Sheik Daher, who haſtened to their aſſiſtance, while Oſman fled without even offering to make the leaſt reſiſtance ; thus leaving the enemy maſters of all Paleſtine without ſtriking a ſtroke. About the end of February 1771, the grand army of Ali Bey arrived ; which, by the repreſentation made of it in Europe, was ſuppoſed to conſiſt of 60,000 men.

114 Volney's account of his army.

M. Volney, however, informs us, that this army was far from containing 60,000 ſoldiers ; though he allows that there might be two-thirds of that number, who were claſſed as follows : 1. Five thouſand Mamlouks, conſtituting the whole effective part of the army. 2. Fifteen hundred Arabs from Barbary on foot, conſtituting the whole infantry of the army. Beſides theſe, the ſervants of the Mamlouks, each of whom had two, would conſtitute a body of 10,000 men. A number of other ſervants would conſtitute a body of 2000 : and the reſt of the number would be made up by ſutlers and other uſual attendants on armies. It was commanded by Mohammed Bey the friend of Ali. "But (ſays our author) as to order and diſcipline, theſe muſt not be mentioned. The armies of the Turks and Mamlouks are nothing but a confuſed multitude of horſemen, without uniforms, on horſes of all colours and ſizes, without either keeping their ranks or obſerving any regular order." This rabble took the road to Acre, leaving wherever they paſſed ſufficient marks of their rapacity and want of diſcipline. At Acre a junction was formed with the troops of Sheik Daher, conſiſting of 1500 Safadians (the name of Sheik Daher's ſubjects, from *Safad*, a village of Galilee, originally under his juriſdiction). Theſe were on horſeback, and accompanied by 1200 Motualis cavalry under the command of Sheik Naſif, and about 1000 Mogrebian infantry. Thus they proceeded towards Damaſcus, while Oſman prepared to oppoſe them by another army equally numerous and ill regulated :

115 Their abſurd method of carrying on war.

and M. Volney gives the following deſcription of their operations : "The reader muſt not here figure to himſelf a number of complicated and artificial movements : ſuch as thoſe which, within the laſt century, have reduced war with us to a ſcience of ſyſtem and calculation. The Aſiatics are unacquainted with the firſt elements of this conduct. Their armies are mere mobs, their marches ravages, their campaigns inroads, and their battles bloody frays. The ſtrongeſt or the moſt adventurous party goes in queſt of the other, which frequently flies without making any reſiſtance. If they ſtand their ground, they engage pell-mell, diſcharge their carabines, break their ſpears, and hack each other with their ſabres ;

for

for they have ſeldom any cannon, and when they have, they are but of little ſervice. A panic frequently diffuſes itſelf without cauſe; one party flies, the other ſhouts victory; the vanquiſhed ſubmit to the will of the conqueror, and the campaign often terminates without a battle.

"Such, in a great meaſure, were the military operations in Syria in the year 1771. The combined army of Ali Bey and Sheik Daher marched to Damaſcus. The pachas waited for them; they approached, and, on the 6th of June, a deciſive action took place: the Mamlouks and Safadians ruſhed on the Turks with ſuch fury that, terrified at their courage, they immediately took to flight, and the pachas were not the laſt in endeavouring to make their eſcape. The allies became maſters of the country, and took poſſeſſion of the city without oppoſition, there being neither walls nor ſoldiers to defend it. The caſtle alone reſiſted. Its ruined fortifications had not a ſingle cannon, much leſs gunners; but it was ſurrounded by a muddy ditch, and behind the ruins were poſted a few muſketeers: and theſe alone were ſufficient to check this army of cavalry. As the beſieged, however, were already conquered by their fears, they capitulated the third day, and the place was to be ſurrendered next morning, when, at day-break, a moſt extraordinary revolution took place.

116 Defection of Ali Bey's general.

This was no leſs than the defection of Mohammed Bey himſelf, whom Oſman had gained over in a conference during the night. At the moment, therefore, that the ſignal of ſurrender was expected, this treacherous general ſounded a retreat, and turned towards Egypt with all his cavalry, flying with as great precipitation as if he had been purſued by a ſuperior army. Mohammed continued his march with ſuch celerity, that the report of his arrival in Egypt reached Cairo only ſix hours before him. Thus Ali Bey found himſelf at once deprived of all his expectations of conqueſt; and what was worſe, found a traitor whom he durſt not puniſh at the head of his forces. A ſudden reverſe of fortune now took place. Several veſſels laden with corn for Sheik Daher were taken by a Ruſſian privateer; and Mohammed Bey, whom he deſigned to have put to death, not only made his eſcape, but was ſo well attended that he could not be attacked. His followers continuing daily to increaſe in number, Mohammed ſoon became ſufficiently ſtrong to march towards Cairo; and, in the month of April 1772, having defeated the troops of Ali in a rencounter, entered the city ſword in hand, while the latter had ſcarce time to make his eſcape with 800 Mamlouks.

117 He is driven out of Cairo, and with difficulty gets into Syria.

With difficulty he was enabled to get to Syria by the aſſiſtance of Sheik Daher, whom he immediately joined with the troops he had with him. The Turks under Oſman were at that time beſieging Sidon, but raiſed the ſiege on the approach of the allied army, conſiſting of about 7000 cavalry.

118 Defeats the Turks, and retrieves his affairs.

Though the Turkiſh army was at leaſt three times their number, the allies did not heſitate to attack them, and gained a complete victory. Their affairs now began to wear a more favourable aſpect; but the military operations were retarded by the ſiege of Yafa, a place which had revolted; and which, though defended only by a garden wall, without any ditch, held out for eight months. In the beginning of 1773 it capitulated, and Ali Bey began to think of returning to Cairo. For this purpoſe Sheik Daher had promiſed to furniſh him with ſuccours; and the Ruſſians, with whom he had now contracted an alliance, made him a promiſe of the like kind.

119 He is ruined by his own impatience.

Ali, however, ruined every thing by his own impatience. Deceived by an aſtrologer, who pretended that the auſpicious moment when he was highly favoured by the ſtars was juſt arrived, he would needs ſet out without waiting for the arrival of his allies. He was alſo farther deceived by a ſtratagem of Mohammed, who had by force extorted from the friends of Ali Bey letters preſſing his return to Cairo, where the people were weary of his ungrateful ſlave, and wanted only his preſence in order to expel him. Confiding in theſe promiſes, Ali Bey imprudently ſet out with his Mamlouks and 1500 Safadians given him by Daher; but had no ſooner entered the deſert which ſeparates Gaza from Egypt, than he was attacked by a body of 1000 choſen Mamlouks who were lying in wait for his arrival. They were commanded by a young bey, named *Mourad;* who being enamoured of the wife of Ali Bey, had obtained a promiſe of her from Mohammed, in caſe he could bring him her huſband's head. As ſoon as Mourad perceived the duſt by which the approach of Ali Bey's armed was announced, he ruſhed upon him, attacked and took priſoner Ali Bey himſelf, after wounding him in the forehead with a ſabre. Being conducted to Mohammed Bey, the latter pretended to treat him with extraordinary reſpect, and ordered a magnificent tent to be erected for him; but in three days he was found dead of his wounds, as was given out; though ſome affirm, perhaps with equal reaſon, that he was poiſoned.

120 Is ſucceeded by Mohammed Bey.

After the death of Ali Bey, Mohammed Bey took upon him the ſupreme dignity; but this change of maſters proved of very little ſervice to the Egyptians. At firſt he pretended to be only the defender of the rights of the ſultan, remitted the uſual tribute to Conſtantinople, and took the cuſtomary oath of unlimited obedience; after which he ſolicited permiſſion to make war upon Sheik Daher, the ally of Ali Bey. The reaſon of this requeſt was a mere perſonal pique; and as ſoon as it was granted, he made the moſt diligent preparations for war. Having procured an extraordinary train of artillery, he provided foreign gunners, and gave the command of them to an Engliſhman named *Robinſon*.

121 His expedition againſt Sheik Daher.

He brought from Suez a cannon 16 feet long, which had for a conſiderable time remained uſeleſs; and at length, in the month of February 1776, he appeared in Syria with an army equal in number to that which he had formerly commanded when in the ſervice of Ali Bey. Daher's forces, deſpairing of being able to cope with ſuch a formidable armament, abandoned Gaza, which Mohammed immediately took poſſeſſion of, and then marched towards a fortified town named Yafa. The hiſtory of this ſiege M. Volney gives as a ſpecimen of the Aſiatic manner of conducting operations of that kind.

122 Account of the ſiege of Yafa: a ſpecimen of the Aſiatic method of beſieging towns.

"Yafa (ſays he), the ancient Joppa, is ſituated on a part of the coaſt, the general level of which is very little above the ſea. The city is built on an eminence, in the form of a ſugar loaf, in height about 130 feet perpendicular. The houſes, diſtributed on the declivity, appear riſing above each other, like the ſteps of an amphitheatre. On the ſummit is a ſmall citadel, which commands the town; the bottom of the hill is ſurrounded by a wall without a rampart, of 12 or 14 feet high, and two or three in thickneſs. The battlements on the top are the only tokens by which it is diſtinguiſhed from a common garden wall. This wall, which has no ditch, is environed by gardens, where lemons, oranges, and citrons, grow in this light ſoil to a moſt prodigious ſize. The city was defended by five or ſix hundred Safadians and as many inhabitants, who, at the ſight of the enemy, armed themſelves with their ſabres and muſkets; they had likewiſe a few braſs cannon, 24 pounders, without carriages; theſe they mounted as well as they could, on timbers prepared in a hurry; and ſupplying the place of experience by hatred and courage, they replied to the ſummons of the enemy with menaces and cannon ſhot.

"Mohammed, finding he muſt have recourſe to force, formed his camp before the town; but was ſo little acquainted with the buſineſs in which he was engaged, that he advanced within half cannon ſhot. The bullets, which ſhowered upon the tents, apprizing him of his error, he retreated; and, by making a freſh experiment, was convinced he was ſtill too near. At length he diſcovered the proper diſtance, and ſet up his tent, in which the moſt extravagant luxury was diſplayed: around it, without any order, were pitched thoſe of the Mamlouks, while the Barbary Arabs formed huts with the trunks and branches of the orange and lemon trees, and the followers of the army arranged themſelves as they could: a few guards were diſtributed here and there; and, without making a ſingle entrenchment, they called themſelves encamped.

"Batteries were now to be erected; and a ſpot of riſing ground was made choice of to the ſouth-eaſtward of the town, where, behind ſome garden walls, eight pieces of cannon were pointed, at 200 paces from the town; and the firing began, notwithſtanding the muſquetry of the enemy, who, from the tops of the terraces, killed ſeveral of the gunners.

"It is evident that a wall only three feet thick, and without a rampart, muſt ſoon have a large breach in it; and the queſtion was not how to mount, but how to get through it? The Mamlouks were for doing it on horſeback; but they were made to comprehend that this was impoſſible; and they conſented, for the firſt time, to march on foot. It muſt have been a curious ſight to ſee them, with their huge breeches of thick Venetian cloth, embarraſſed with their tucked-up *beniches*, their crooked ſabres in hand, and piſtols hanging at their ſides, advancing and tumbling among the ruins of the wall. They imagined that they had conquered every difficulty when this obſtacle was ſurmounted; but the beſieged, who formed a better judgment, waited till they arrived at the empty ſpace between the city and wall; where they aſſailed them from the terraces and windows of the houſes with ſuch a ſhower of bullets, that the Mamlouks did not ſo much as think of ſetting them on fire, but retired under a perſuaſion that the breach was utterly impracticable, ſince it was impoſſible to enter it on horſeback. Morad Bey brought them ſeveral times back to the charge, but in vain.

"Six weeks paſſed in this manner; and Mohammed was diſtracted with rage, anxiety, and deſpair. The beſieged however, whoſe numbers were diminiſhed by the repeated attacks, became weary of defending alone the cauſe of Daher. Some perſons began to treat with the enemy; and it was propoſed to abandon the place, on the Egyptians giving hoſtages. Conditions were agreed upon, and the treaty might be conſidered as concluded, when, in the midſt of the ſecurity occaſioned by this belief, ſome Mamlouks entered the town; numbers of others followed their example, and attempted to plunder. The inhabitants defended themſelves, and the attack recommenced: the whole army then ruſhed into the town, which ſuffered all the horrors of war; men, women and children, young and old, were all cut to pieces, and Mohammed, equally mean and barbarous, cauſed a pyramid formed of the heads of theſe unfortunate ſufferers to be raiſed as a monument of his victory."

123
The town taken and the inhabitants maſſacred.

By this diſaſter the greateſt terror and conſternation were everywhere diffuſed. Sheik Daher himſelf fled, and Mohammed ſoon became maſter of Acre alſo. Here he behaved with his uſual cruelty, and abandoned the city to be plundered by his ſoldiers. The French merchants claimed an exemption, and it was procured with the utmoſt difficulty: nor was even this likely to be of any conſequence; for Mohammed, informed that the treaſures of Ibrahim kiaya of Daher had been depoſited in that place, made an immediate demand of them, threatening every one of the merchants with death if the treaſures were not inſtantly produced. A day was appointed for making the ſearch; but before this came, the tyrant himſelf died of a malignant fever after two days illneſs. His death was no ſooner known than the army made a precipitate retreat, ſuch as has been already mentioned from Damaſcus. Sheik Daher continued his rebellion for ſome time, but was at laſt entirely defeated, and his head ſent to Conſtantinople by Haſſan Pacha the Turkiſh high-admiral.

124
Death of Mohammed Bey.

125
Hiſtory of Egypt from that time to the year 1786.

The death of Mohammed was no ſooner known in Egypt, than Morad Bey haſtened to Cairo in order to diſpute the ſovereignty with Ibrahim Bey, who had been intruſted with the government on his departure from that place for Syria. Preparations for war were made on both ſides; but at laſt, both parties finding that the conteſt muſt be attended with great difficulty, as well as very uncertain in the event, thought proper to come to an accommodation, by which it was agreed that Ibrahim ſhould retain the title of Sheik El Beled, and the power was to be divided between them. But now the beys and others who had been promoted by Ali Bey, perceiving their own importance totally annihilated by this new faction, reſolved to ſhake off the yoke, and therefore united in a league under the title *of the Houſe of Ali Bey*. They conducted their matters with ſo much ſilence and dexterity, that both Morad and Ibrahim were obliged to abandon Cairo. In a ſhort time, however, they returned and defeated their enemies though three times their number; but notwithſtanding this ſucceſs, it was not in their power totally to ſuppreſs the party. This indeed was owing entirely to their unſkilfulneſs in the art of war, and their operations for ſome time were very trifling. At laſt, a new combination having been formed among the beys, five of them were ſentenced to baniſhment in the Delta. They pretended to comply with this order, but took the road of the Deſert of the Pyramids, through which they were purſued for three days to no purpoſe. At laſt they arrived ſafe at *Miniah*, a village ſituated on the Nile, 40 leagues above Cairo. Here

Here they took up their reſidence, and being maſters of the river, ſoon reduced Cairo to diſtreſs by intercepting its proviſions. Thus a new expedition became neceſſary, and Ibrahim took the command of it upon himſelf. In the month of October 1783 he ſet out with an army of 3000 cavalry; the two armies ſoon came in ſight of each other, but Ibrahim thought proper to terminate the affair by negociation. This gave ſuch offence to Morad, who ſuſpected ſome plot againſt himſelf, that he left Cairo. A war betwixt the two rivals was now daily expected, and the armies continued for 25 days in ſight of each other, only ſeparated by the river. Negociations took place; and the five exiled beys, finding themſelves abandoned by Morad, took to flight, but were purſued and brought back to Cairo. Peace ſeemed now to be re-eſtabliſhed; but the jealouſy of the two rivals producing new intrigues, Morad was once more obliged to quit Cairo in 1784. Forming his camp, however, directly at the gates of the city, he appeared ſo terrible to Ibrahim, that the latter thought proper in his turn to retire to the deſert, where he remained till March 1785. A new treaty then took place; by which the rivals agreed to ſhare the power between them, though there was certainly very little probability that ſuch a treaty would be long obſerved. Since that time we have no accounts of any remarkable tranſaction in Egypt; nor indeed can we reaſonably expect any thing of conſequence in a country where matters are managed, as M. Volney expreſſes himſelf, by a ſeries of "cabals, intrigues, treachery, and murders."

Of late Egypt has been viſited by ſeveral travellers, all of whom have publiſhed deſcriptions of the country, its productions, inhabitants, &c. The lateſt are M. Savary, M. Volney, the baron de Tott, and Mr Bruce; and from the accounts publiſhed by thoſe gentlemen the following geographical deſcription is principally compiled.

126
Account of the country.

This country is ſtill divided into two principal parts, called the *Upper* and *Lower Egypt*. According to M. Savary, the former is only a long narrow valley beginning at Syene and terminating at Cairo. It is bounded by two chains of mountains running from north to ſouth, and taking their riſe from the laſt cataract of the Nile. On reaching the latitude of Cairo they ſeparate to the right and left; the one taking the direction of Mount Colzoum, the other terminating in ſome ſand banks near Alexandria; the former being compoſed of high and ſteep rocks, the latter of ſandy hillocks over a bed of calcareous ſtone. Beyond theſe mountains are deſerts bounded by the Red ſea on the eaſt, and on the weſt by other parts of Africa; having in the middle that long plain which, even where wideſt, is not more than nine leagues over. Here the Nile is confined in its courſe betwixt theſe inſuperable barriers, and during the time of its inundation overflows the country all the way to the foot of the mountains; and Mr Bruce obſerves that there is a gradual ſlope from the bed of the river to thoſe mountains on both ſides. The baron de Tott ſays, that the mountains four leagues from the Nile, and facing Cairo, "are only a ridge of rocks of about 40 or 50 feet high, which divide Egypt from the plains of Libya; which ridge accompanies the courſe of the river, at a greater or leſſer diſtance, and ſeems as if only intended to ſerve as a bank to the general innndution."

Lower Egypt, according to M. Savary, comprehends all the country between Cairo, the Mediterranean, the iſthmus of Suez and Libya. "This immenſe plain (ſays he) preſents on the borders of its parching ſands a ſtrip of lands cultivated along the canals of the river, and in the middle a triangular iſland to which the Greeks gave the name of *Delta;* at the top of the angle of which the baron de Tott informs us the rocks of Libya and the coaſts of Arabia open and recede from each other towards the eaſt and weſt, parallel to the Mediterranean. This great extent of country, from the kingdom of Barca to Gaza, is either overflowed by the river, or capable of being ſo; which thus fertilizes in a high degree a tract of country ſeemingly devoted to perpetual barrenneſs on account of the want of rain and the heat of the climate.

127
Coaſt of Egypt extremely low.

According to the teſtimonies of both Mr Bruce and M. Volney, the coaſt of Egypt is ſo extremely low, that it cannot be diſcovered at ſea till the mariners come within a few leagues of it. In ancient times the ſailors pretended to know when they approached this country, by a kind of black mud brought up by their ſounding line from the bottom of the ſea; but this notion, though as old as the days of Herodotus, has been diſcovered to be a miſtake by Mr Bruce; who found the mud in queſtion to ariſe while the veſſel was oppoſite to the deſerts of Barca. All along the coaſt of Egypt a ſtrong current ſets to the eaſtward.

128
Of the fertility of ancient and modern Egypt.

In former times Egypt was much celebrated for its fertility; and there is great reaſon to believe, that were the ſame pains beſtowed upon the cultivation of the ground, and the diſtribution of the waters of the Nile in a proper manner, the ſame fertility would ſtill be found to remain. The cauſe of decreaſe in the produce of Egypt we ſhall deſcribe in the words of M. Savary. "The canals," ſays he, ſpeaking of the Delta, "which uſed to convey fertility with their waters, are now filled. The earth no longer watered, and continually expoſed to the burning ardour of the ſun, is converted into a barren ſand. In thoſe places where formerly were ſeen rich fields and flouriſhing towns, on the Peluſiac, the Tarictic, and the Mendeſian branches, which all ſtrike out from the canal of Damietta, nothing is to be found at this day but a few miſerable hamlets, ſurrounded by date trees and by deſerts. Theſe once navigable canals are now no more than a vain reſemblance of what they were: they have no communication with the lake Menzall, but what is merely temporary, on the ſwelling of the Nile; they are dry the remainder of the year. By deepening them by removing the mud depoſited by the river ſince the Turks have made themſelves maſters of Egypt, the country they paſs through would be again fertilized, and the Delta recover a third of its greatneſs."

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Savary's account of the formation of the Delta.

Concerning this iſland it has been the opinion of a great many, even from very ancient times, that it was produced by the mud brought down by the inundations of the Nile: and this opinion we find adopted in the ſtrongeſt manner by M. Savary. His account of the ſuppoſed riſe of the Delta, and indeed of the greateſt part of Egypt, is to the following purpoſe.

In

In thoſe early ages where hiſtory has not fixed any epoch, a certain people deſcended from the mountains near the cataracts into the valley overflowed by the Nile, and which was then an uninhabitable moraſs overgrown with reeds and canes. In what manner, or from what motive, theſe people were induced to deſcend from their ancient habitations to ſuch a place, or how they found means to penetrate into a moraſs which he expreſsly tells us was *impenetrable*, we are not informed, neither is it to our preſent purpoſe to inquire. At that time, however, the ſea bathed the feet of thoſe mountains where the pyramids are built, and advanced far into Libya. It covered alſo part of the iſthmus of Suez, and every part of what we now call the Delta formed a great gulf. After many ages the Egyptians, by what means is unknown, at leaſt not ſpecified by our author (though they ought to have been ſo, as the country it ſeems was then overflowed not only by the river but by the ocean), formed canals to carry off the ſtagnant waters of the Nile; oppoſed ſtrong dykes to its ravages; and, tired of dwelling in the caverns of rocks, built towns and cities upon ſpots elevated either by nature or art. Already the river was kept within its bounds, the habitations of men were out of the reach of its inundations, and experience had taught the people to foreſee and announce them. One of the kings of Egypt undertook to change the courſe of the river. After running 250 leagues between the barriers already mentioned, meeting with an unſurmountable obſtacle to the right, it turned ſuddenly to the left; and taking its courſe to the ſouthward of Memphis, it ſpreads its waters through the ſands of Libya. The prince we ſpeak of cauſed a new bed to be dug for it to the eaſt of Memphis; and by means of a large dyke obliged it to return between the mountains, and diſcharge itſelf into the gulf that bathes the rock on which the caſtle of Cairo is built. The ancient bed of the river was ſtill to be ſeen in the time of Herodotus, and may even be traced at this day acroſs the deſerts, paſſing to the weſtward of the lakes of natrum. The Arabs ſtill beſtow upon it the name of *Bahr Belama*, "or ſea without watee," and it is now almoſt choked up. To the labours of this monarch Egypt is indebted for the Delta. A reflux of the ſea was occaſioned by the enormous weight of the waters of the Nile, which precipitated themſelves into the bottom of the gulf. Thus the ſands and mud carried along with them were collected into heaps; and thus the Delta, at firſt very inconſiderable, roſe out of the ſea, of which it repelled the limits. It was a gift of the river, and it has ſince been defended from the attacks of the ocean by raiſing dykes around it. Five hundred years before the Trojan war, according to Herodotus, the Delta was in its infancy; eight cubits of water being then ſufficient to overflow it. Strabo tells us, that boats paſſed over it from one extremity to the other; and that its towns, built upon artificial eminences, reſembled the iſlands of the Egean ſea. At the time that Herodotus viſited this country, 15 cubits were neceſſary to cover all the Lower Egypt; but the Nile then overflowed the country for the ſpace of two days journey to the right and left of the iſland. Under the Roman empire 16 cubits performed the ſame effect. When the Arabs came to have the dominion, 17 cubits were requiſite; and at this day 18 are neceſſary to produce a plentiful crop; but the inundation ſtops at Cairo and the neighbouring country, without being extended over the Lower Egypt. Sometimes, however, the Nile riſes to 22 cubits; and the cauſe of this phenomenon is the mud for ſo many years accumulated on the iſland. Here, in the ſpace of 3284 years, we ſee the Delta elevated 14 cubits. Our author wrote in 1777, and informs us that he twice made the tour of the iſland during the time of the inundation. "The river (ſays he) flowed in full ſtreams in the great branches of Roſetta and Damietta, as well as in thoſe which paſs through the interior part of the country; but it did not overflow the lands, except in the lower parts, where the dykes were pierced for the purpoſe of watering the plantations of rice. We muſt not, however, imagine, as ſeveral travellers pretend, that this iſland will continue to riſe, and that it will become unfruitful. As it owes its increaſe to the annual ſettling of the mud conveyed thither by the Nile, when it ceaſes to be overflowed it will no longer increaſe in height, for it is demonſtrated that culture is not ſufficient to raiſe land.

"It is natural to imagine that the Delta has increaſed in length as well as in height; and of this we may look upon the following fact to be a remarkable proof. Under the reign of Pſammiticus, the Mileſians, with 30 veſſels, landed at the mouth of the Bolbitine branch of the Nile, now called that of *Roſetta*, where they fortified themſelves. There they built a town called *Metelis*, the ſame as *Faoüe*, which, in the Coptic vocabularies, has preſerved the name of *Meſſil*. This town, formerly a ſeaport, is now nine leagues diſtant from the ſea; all which ſpace the Delta has increaſed in length from the time of Pſammiticus to the preſent. Homer, in his Odyſſey, puts the following words in the mouth of Menelaus. 'In the ſtormy ſea which waſhes Egypt there is an iſland called *Pharos*. Its diſtance from the ſhore is ſuch, that a veſſel with a fair wind may make the paſſage in a day.' From the way in which he ſpeaks of this iſland in other places, alſo, we may ſuppoſe that the iſland of Pharos, in his time, was not leſs than 20 leagues diſtant from the Egyptian coaſt, though now it forms the port of Alexandria; and this ſentiment is confirmed by the moſt ancient writers.

"What prodigious changes great rivers occaſion on the ſurface of the globe! How they elevate, at their mouths, iſlands which become at length large portions of the continent! It is thus that the Nile has formed almoſt all the Lower Egypt, and created out of the waters the Delta, which is 90 leagues in circumference. It is thus that the Meander, conſtantly repelling the waves of the Mediterranean, and gradually filling up the gulf into which it falls, has placed in the middle of the land the town of Miletus, formerly a celebrated harbour. It is thus that the Tigris and the Euphrates, let looſe from the Armenian hills, and ſweeping with them in their courſe the ſands of Meſopotamia, are imperceptibly filling up the Perſian gulf."

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Mr Bruce's reaſons for the contrary opinion.

Theſe are the reaſons aſſigned by M. Savary for thinking that the Delta, as well as the greateſt part of the Lower Egypt, had been produced by the Nile; but this opinion is violently conteſted by other travellers, particularly Mr Bruce, who has given a pretty long diſſertation upon it, as well as many occaſional remarks through the courſe of his work. He begins with obſerving, 1. That the country of Egypt is entirely a valley bounded by rugged mountains; whence it might ſeem natural to imagine that the Nile, overflowing a country of this kind, would be more ready to waſh away the ſoil than add to it. 2. It is obſerved by Dr Shaw, and the ſame is confirmed by our author, that there is a gentle ſlope from the middle of the valley to the foot of the mountains on each ſide; ſo that the middle, in which is the channel of the Nile, is really higher than any other part of the valley. Large trenches are cut acroſs the country from the channel of the river, and at right angles with it, to the foot of the mountains. 3. As the river ſwells, the canals become filled with water, which naturally deſcending to the foot of the mountains, runs out at the farther end, and overflows the adjacent level country. 4. When the water, having attained the loweſt ground, begins to ſtagnate, it does not acquire any motion by reaſon of the canal's being at right angles with the channel of the Nile, unleſs in the caſe of exceſſive rains in Ethiopia, when the water by its regurgitation again joins the ſtream. In this caſe, the motion of the current is communicated to the whole maſs of waters, and every thing is ſwept away by them into the ſea. 5. It has been the opinion of ſeveral authors, that there was a neceſſity for meaſuring the height of the inundation on account of the quantity of mud brought down annually by the waters, by which the landmarks were ſo covered, that the proprietors could not know their own grounds after the river ſubſided. But whatever might be the reaſon of this covering of the landmarks in ancient times, it is certain that the mud left by the Nile could not be ſo in the time of Herodotus, or during any period of time aſſigned by that hiſtorian; for he aſſigns only one foot of increaſe of ſoil throughout Egypt in an hundred years from the mud left by the river; the increaſe during one year, therefore, being only the hundredth part of a foot, could not cover any landmark whatever. Beſides, the Egyptian lands are at this day parted by huge blocks of granite, which frequently have gigantic heads at the end of them; and theſe could not, at the rate mentioned by Herodotus, be covered in ſeveral thouſand years. 6. The Nile does not now bring down any great quantity of mud; and it is abſurd to ſuppoſe that it can at preſent bring down as much as it did ſoon after the creation, or the ages immediately ſucceeding the deluge. Throughout Abyſſinia, according to the teſtimony of our author, the channel of every torrent is now worn to the bare rock, and almoſt every rivulet runs in a hard ſtony bed, all the looſe earth being long ago waſhed away; ſo that an annual and equable increaſe of the earth from the ſediment of the waters is impoſſible. 7. Our author made a great number of trials of the water of the Nile during the time of its inundation in different places. At Baſboch, when juſt coming down from the cultivated parts of Abyſſinia, and before it enters Sennaar, the ſediment is compoſed of fat earth and ſand, and its quantity is exceedingly ſmall. At the junction of the Nile and Aſtaboras the quantity of ſediment is very little augmented; conſiſting ſtill of the ſame materials, but now moſtly ſand. At Syene the quantity of ſediment was almoſt nine times greater than before; but was now compoſed almoſt entirely of ſand, with a very ſmall quantity of black earth. The concluſion of our author's experiments, however, is different from what we ſhould have been led to expect from thoſe juſt mentioned. "The experiment at Roſetta (ſays he) was not ſo often repeated as the others: but the reſult was, that in the ſtrength of the inundation the ſediment conſiſted moſtly of ſand; and, towards the end, was much the greater part earth. I think theſe experiments concluſive, as neither the Nile coming freſh from Abyſſinia, nor the Atbara, though joined by the Mareb, likewiſe from the ſame country, brought any great quantity of ſoil from thence."

8. Our author goes on to obſerve, that had the Nile brought down the quantities of mud which it has been ſaid to do, it ought to have been moſt charged with it at Syene; as there it contained the whole that was to be conveyed by it into Egypt. Inſtead of this, however, the principal part of the ſediment at this place was ſand; and this is very naturally accounted for from the vaſt quantities of ſand taken up by the winds in the deſerts between Gooz and Syene. Here our traveller frequently ſaw vaſt pillars of this kind of ſand, which is ſo fine and light as to form an impalpable powder, traverſing the deſert in various directions. Many of theſe were driven upon the river; and when it became calm in the evening, fell down into it entirely; thus affording materials for the many ſandy iſlands to be met with in the Nile.

9. Mr Bruce adopts the opinion of thoſe who ſuppoſe that there has been a continual decreaſe of water ſince the creation of the world. In this caſe, therefore, if the land of Egypt had been continually increaſing in height while the water that was to cover it decreaſed; there muſt have been frequent famines on account of the want of a ſufficient inundation. But ſo far is this from being the caſe, that, according to the teſtimony of ſeveral Arabian MSS. there had not, when Mr Bruce was in Egypt, been one ſcarce ſeaſon from the lowneſs of the inundation for 34 years; though during the ſame ſpace they had three times experienced a famine by too great an abundance of water, which carried away the millet.

10. If there had been ſuch an increaſe of land as Herodotus and others ſuppoſe, it muſt now have been very perceptible in ſome of the moſt ancient public monuments. This, however, is by no means the caſe. The baſe of every obeliſk in Upper Egypt is to this day quite bare and viſible. Near Thebes there are ſtill extant two coloſſal ſtatues, plainly deſigned for nilometers, and which ought by this time to have been almoſt covered with earth; but notwithſtanding the length of time theſe have remained there, they are ſtill bare to the very baſe.

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Opinions of various authors concerning the riſe of the Nile in ancient times.

The ſtrongeſt argument which the advocates for the increaſe of land of Egypt can make uſe of is, that the meaſures by which the quantity of inundation is determined are ſmaller now than in former times; and theſe ſmall meaſures are ſaid to have been introduced by the Saracens. On this Mr Bruce very juſtly obſerves, that ſuch an expedient could not have anſwered any good purpoſe; as no decreaſe of the meaſure could have augmented the quantity of corn produced by the ground. M. Savary obſerves, that, to render his calculation concerning the growth of land in Egypt abſolutely exact, it would be neceſſary to determine the

the preciſe length of the Greek, Roman, and Arabian cubit; and even to know the different alterations which that meaſure had undergone among theſe people: But this nicety he thinks needleſs; looking upon the general fact to be fully eſtabliſhed by what he had ſaid before. Mr Bruce, however, has treated the ſubject with much greater accuracy. He obſerves, that from the ſituation of Canopus, the diſtance betwixt Egypt and Cyprus, and the extenſion of the land to the northward, it appears that no addition of any conſequence has been made to it for 3000 years paſt. The only argument left for the increaſe of land therefore muſt be taken from the nilometer. The uſe of this inſtrument was to determine the quantity of inundation, that ſo it might be known whether the crop would be ſufficient to enable the people to pay the taxes exacted of them by the ſovereign or not. The firſt ſtep was to know what ſpace of ground was overflowed in a given number of years; and this being determined by menſuration, the next thing was to aſcertain the produce of the ground upon an average. Thus becoming acquainted with the greateſt and leaſt crops produced, together with the exact extent of ground overflowed, they were furniſhed with all the neceſſary principles for conſtructing a nilometer; and nothing now remained but to erect a pillar in a proper place, and divide it exactly into cubits. This was accordingly done; the pillar was firſt divided into cubits, and theſe again were ſubdivided into digits. The firſt diviſion of this kind was undoubtedly that mentioned in Scripture, and called the *cubit of a man;* being the length of the arm from the middle of the round bone in the elbow to the point of the middle finger; a meaſure ſtill in uſe among all rude nations. As no ſtandard could be found by which this meaſure might be exactly determined, authors have differed very much concerning the true length of the cubit when reduced to our feet and inches. Dr Arbuthnot reckons two cubits mentioned in Scripture; one of them containing one foot nine inches and $\frac{888}{1000}$ of an inch; the other one foot and $\frac{824}{1000}$ of a foot; but Mr Bruce is of opinion that both of theſe are too large. He found, by menſuration, the Egyptian cubit to be exactly one foot five inches and three-fifths of an inch; and Herodotus mentions, that in his time the cubit uſed for determining the increaſe of the Nile was the Samian cubit, about 18 of our inches. The latter alſo informs us, that in the time of Moeris, the minimum of increaſe was 8 cubits, at which time all Egypt below the city of Memphis was overflowed; but that in his time 16 or at leaſt 15 cubits were neceſſary to produce the ſame effect. But to this account Mr Bruce objects, that Herodotus could have no certain information concerning the nilometer, becauſe he himſelf ſays that the prieſts, who alone had acceſs to it, would tell him nothing of the matter. Herodotus alſo informs us, that in the time of Moeris, great lakes were dug to carry off the waters of the inundation; and this ſuperfluous quantity Mr Bruce ſuppoſes to have been conveyed into the deſert for the uſe of the Arabs, and that by ſuch a vaſt drain the riſe of the water on the nilometer would undoubtedly be diminiſhed. But even granting that there was ſuch a difference between the riſe of the water in the time of Moeris and in that of Herodotus, it does not appear that any thing like it has appeared ever ſince. Strabo, who travelled into Egypt 400 years after the time of Herodotus, found that eight cubits were then the minimum, as well as in the time of Moeris. From ſome paſſages in Strabo, however, it appears that it required a particular exertion of induſtry to cauſe this quantity of water produce a plentiful crop; but there is not the leaſt reaſon to ſuppoſe, that the very ſame induſtry was not neceſſary in the time of Moeris; ſo that ſtill there is not any increaſe of land indicated by the nilometer. About 100 years afterwards, when the emperor Adrian viſited Egypt, we are informed from unqueſtionable authority, that 16 cubits were the minimum when the people were able to pay their tribute; and in the fourth century, under the emperor Julian, 15 cubits were the ſtandard; both which accounts correſpond with that of Herodotus. Laſtly, Procopius, who lived in the time of Juſtinian, informs us, that 18 cubits were then requiſite for a minimum.

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No increaſe of land in theſe ages can reaſonably be ſuppoſed;

From theſe accounts, ſo various and diſcordant, it is obvious that no certain concluſion can be drawn. It is not indeed eaſy to determine the reaſon of this difference in point of fact. The only conjecture we can offer is, that as it appears that by proper care a ſmaller quantity of water will anſwer the purpoſe of producing a plentiful crop, ſo it is not unreaſonable to ſuppoſe that at different periods the induſtry of the people has varied ſo much as to occaſion the diſagreement in queſtion. This would undoubtedly depend very much upon their governor; and indeed Strabo informs us that it was by the care of the governor Petronius, that ſuch a ſmall quantity of water was made to anſwer the purpoſe. The concluſion drawn by Mr Bruce from the whole of the accounts above related, is, that from them it is moſt probable that no increaſe of land has been indicated by the nilometer from the time of Moeris to that of Juſtinian.

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nor in more modern times.

On the conqueſt of Egypt by the Saracens, their barbarous and ſtupid caliph deſtroyed the nilometer, cauſing another to be built in its ſtead, and afterwards fixed the ſtandard of paying tribute conſiderably below what it had uſually been. The Egyptians were thus kept in continual terror, and conſtantly watched the new nilometer to obſerve the gradual increaſe or decreaſe of the water. On this he ordered the new nilometer to be deſtroyed, and another to be conſtructed, and all acceſs to it to be denied to the people. Which prohibition is ſtill continued to Chriſtians; though our author found means to get over this obſtacle, and has given a figure of the inſtrument itſelf. That the people might not, however, be ſuppoſed to remain in total ignorance of their ſituation, he commanded a proclamation to be daily made concerning the height of the water, but in ſuch an unintelligible manner that nobody was made any wiſer; nor, according to our author, is the proclamation underſtood at this day. From his own obſervations, however, Mr Bruce concludes, that 15 cubits are now the minimum of inundation, and as this coincides with the accounts of it in the times of Herodotus and Adrian, he ſuppoſes with great probability, that the ſame quantity of water has been neceſſary to overflow this country from the earlieſt accounts to the preſent time.

It now remains only to take notice of what is ſaid by M. Savary concerning the former diſtance of the iſland of Pharos from the land to which it is now joined.

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M. Savary's opinion concerning the iſle of Pharos refuted by M. Volney.

With regard to his other aſſertions concerning the city of Metelis having been once a ſea port, M. Volney proves that he has quoted Strabo unfairly, and conſequently no ſtreſs is to be laid upon them. The principal, indeed the only, evidence which therefore remains, is the paſſage already quoted from Homer, viz. that “ the iſland of Pharos is as far diſtant from one of the mouths of the Nile as a veſſel can ſail in one day before the wind.” “ But (ſays M. Volney) when Homer ſpeaks of the diſtance of this iſland, he does not mean its diſtance from the ſhore oppoſite, as that traveller (M. Savary) has tranſlated him, but from the land of Egypt and the river Nile. In the ſecond place, by a day's ſail we muſt not underſtand that indefinite ſpace which the veſſels, or rather the boats, of the ancient Greeks, could paſs through in a day; but an accurate and determined meaſure of 540 ſtadia. This meaſure is aſcertained by Herodotus, and is the preciſe diſtance between Pharos and the Nile, allowing, with M. d'Anville, 27,000 toiſes to 540 ſtadia. It is therefore far from being proved, that the increaſe of the Delta or of the continent was ſo rapid as has been repreſented; and, if we were diſpoſed to maintain it, we ſhould ſtill have to explain how this ſhore, which has not gained half a league from the days of Alexander, ſhould have gained eleven in the far ſhorter period from the time of Menelaus to that conqueror. The utmoſt extent of the encroachment of this land upon the ſea, however, may be learned from the words of Herodotus; who informs us, that “ the breadth of Egypt, along the ſea coaſt, from the gulf of Plinthine to the lake Serbonis near Mount Caſius, is 3600 ſtadia; and its length from the ſea to Heliopolis 1500 ſtadia.” Allowing therefore the ſtadium of Herodotus to be between 50 and 51 French toiſes, the 1500 ſtadia juſt mentioned are equal to 76,000 toiſes; which, at the rate of 57,000 to a degree, gives one degree and near 20 minutes and a half. But from the aſtronomical obſervations of M. Niebuhr, who travelled for the king of Denmark in 1761, the difference of latitude between Heliopolis, now called *Matarea*, and the ſea, being one degree 29 minutes at Damietta, and one degree 24 minutes at Roſetta, there is a difference on one ſide of three minutes and a half, or a league and a half encroachment; and eight minutes and a half, or three leagues and a half on the other.”

Thus the diſpute concerning the augmentation of the land of Egypt by the Nile ſeems to be abſolutely decided; and the encroachments of it on the ſea ſo trifling, that we may juſtly doubt whether they exiſt, or whether we are not entirely to attribute the apparent differences to thoſe which certainly take place betwixt the ancient and modern menſuration. M. Volney gives a very particular deſcription of the face of the country; but takes notice of the inconveniences under which travellers labour in this country, by which it is rendered extremely difficult to ſay any thing certain with regard to the nature of the ſoil or mineral productions. Theſe ariſe from the barbarity and ſuperſtition of the people, who imagine all the Europeans to be magicians and ſorcerers, who come by their magic art to diſcover the treaſures which the genii have concealed under the ruins. So deep-rooted is this opinion, that no perſon dares walk alone in the fields, nor can he find any one willing to accompany him; by which means he is confined to the banks of the river, and it is only by comparing the accounts of various travellers that any ſatisfactory knowledge can be acquired.

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Volney's account of the face of the country.

According to this author, the entrance into Egypt at Roſetta preſents a moſt delightful proſpect, by the perpetual verdure of the palm trees on each ſide, the orchards watered by the river, with orange, lemon, and other fruit trees, which grow there in vaſt abundance; and the ſame beautiful appearance is continued all the way to Cairo. As we proceed farther up the river, he ſays, that nothing can more reſemble the appearance of the country than the marſhes of the Lower Loire, or the plains of Flanders: inſtead, however, of the numerous trees and country houſes of the latter, we muſt imagine ſome thin woods of palms and ſcyamores, with a few villages of mud-walled cottages built on artificial mounds. All this part of Egypt is very low and flat, the declivity of the river being ſo gentle, that its waters do not flow at a greater rate than one league in an hour. Throughout the country nothing is to be ſeen but palm trees, ſingle or in clumps, which become more rare in proportion as you advance; with wretched villages compoſed of huts with mud walls, and a boundleſs plain, which at different ſeaſons is an ocean of freſh water, a miry moraſs, a verdant field, or a duſty deſert; and on every ſide an extenſive and foggy horizon, where the eye is wearied and diſguſted. At length, towards the junction of the two branches of the river, the mountains of Cairo are diſcovered on the eaſt; and to the ſouth-weſt three detached maſſes appear, which from their triangular form are known to be the pyramids. We now enter a valley which turns to the ſouthward, between two chains of parallel eminences. That to the eaſt, which extends to the Red ſea, merits the name of a mountain from its ſteepneſs and height, as well as that of a deſert from its naked and ſavage appearance. Its name in the Arabic language is *Mokattam*, or the *hewn mountain*. The weſtern is nothing but a ridge of rock covered with ſand, which has been very properly termed a *natural mound* or *cauſeway*. In ſhort, that the reader may at once form an idea of this country, let him imagine on one ſide a narrow ſea and rocks; on the other, immenſe plains of ſand; and in the middle, a river, flowing through a valley of 150 leagues in length and from three to ſeven wide, which at the diſtance of 30 leagues from the ſea ſeparates into two arms; the branches of which wander over a ſoil almoſt free from obſtacles, and void of declivity.

From comparing his own obſervations with thoſe of other travellers, our author concludes, that the baſis of all Egypt from *Aſouan* (the ancient Syene) to the Mediterranean, is a continued bed of calcareous ſtone of whitiſh hue, and ſomewhat ſoft, containing the ſame kind of ſhells met with in the adjacent ſeas, and which forms the immenſe quarries extending from Saouadi to Manfalout for the ſpace of more than 25 leagues, according to the teſtimony of Father Sicard.

136
Reynier's

As this country has been more recently viſited by men of eminent abilities and profound reſearch, who appear to have examined every object that preſented itſelf with a philoſopher's eye, we beg leave to add to the teſtimonies of the authors already mentioned, the ſubſtance of the French general Reynier's account of the face of the country. He informs us, that the barriers by which Egypt is incloſed muſt be ſtrong, becauſe they have been planted by the hand of nature.

It is ſeparated from Aſia by deſerts of conſiderable extent; and ſhould an hoſtile army attempt to approach it on that ſide, it would have to take its route through marſhy grounds below its general level, and preſenting to the traveller little elſe than brackiſh water. Its flat ſhore towards the Mediterranean, and the mouths of the Nile gorged up with mounds of ſand, preſent to an enemy very few places which will be found proper for the debarkation of troops. Immenſe deſerts conſtitute its natural boundaries on the weſt, on which account it has nothing to dread but the incurſions of the Arabs from Barbary. A deſert alſo ſeparates Egypt from the Red ſea, which gives no flattering invitations to an enemy to invade it from that quarter, the two ports of that ſea being deſtitute of reſources, and Egypt itſelf being the only country from which a hoſtile army could procure proviſions and camels, ſufficient to enable it to croſs the deſert.

In upper Egypt, a chain of mountains preſent themſelves to the eye of the traveller on either ſide of the Nile. The valley between theſe mountains, through which the courſe of the river is directed, is nearly five leagues broad, which the periodical inundations of the river completely cover. This valley alone is inhabited, and ſuſceptible of cultivation. The eaſtern chain of mountains, by which the Nile is ſeparated from the Red ſea, ſurpaſſes that on the weſt in reſpect of height, terminating by precipices towards the valley, aſſuming in different places the appearance of an immenſe wall, broken irregularly by narrow valleys, which have owed their origin to the ſudden and temporary torrents of winter, and ſerve for paſſes over theſe ſtupendous mountains. The weſtern chain, by which the valley of the Nile is ſeparated from that of Ouaſis, has in general a gradual and gentle declivity, although it becomes more abrupt towards Siout, and is ſteep from the angle formed by the Nile towards Hennh, till it reaches Syene, at which place the mountains have a more conſiderable height, affording but a narrow paſſage to the river.

The diſtance between theſe two chains of mountains is increaſed as you approach Cairo, the eaſtern chain terminating near the extremity of the Red ſea, without the appearance of any junction with the Arabian mountains, which have a ſimilar termination. The weſtern chain declines towards Fayeum, taking a north-weſt direction near Grand Cairo, and forming the Mediterranean coaſt in a direction to the weſt. Lower Egypt lies between theſe two great chains of mountains and the ſea, which has moſt probably been formed, at leaſt in a great meaſure, by the ſlime or mud which the river Nile depoſits, as it is interſected by its branches, and a vaſt number of canals.

The ſeven branches by which the Nile anciently emptied itſelf into the Mediterranean, are at preſent reduced to two, viz. thoſe of Damietta and Roſetta. There are now no veſtiges of the other five, except a canal or two, which are only navigable during a part of the year. It is not improbable, that when all the branches of the Nile were entire and diſtinct, each of them contained about the ſame quantity of water. The cutting of canals to effect the equilibrium of the water, the channels of which were afterwards neglected, would diminiſh the quantum of water in one branch and increaſe it in another. The ſalt water mingling with the freſh, would deſtroy the fecundity of the ground in ſome places, aad thus induce the inhabitants to ſearch for habitations where they might find the earth more fertile.

It has already been obſerved, that the principal part of Lower Egypt owes its exiſtence to the depoſition of mud or earth by the Nile, which alſo formed the banks at the different mouths of that river. The mud of the Nile would firſt cover the low ground neareſt to its bed or channel, and the increaſe of land from the depoſition of mud would be more gradual in its progreſs in diſtant parts, from which circumſtance would ariſe the formation of lakes. Theſe in their turn would be gradually filled up by the land growing out of the depoſited mud of the river, which of conſequence would increaſe the boundaries of Lower Egypt, by taking from the ſea; but as it is natural for the ſea to reſiſt ſuch encroachments, it is probable that the ground formed by the depoſited mud of the Nile will no longer continue to increaſe in one direction without diminiſhing in another. The experience of centuries paſt has fully evinced, that the ſea has actually taken more from the extent of Egypt than has been compenſated by the mud of the Nile. By the ſimple operation of natural cauſes it may be ſafely concluded, that if nature and art do not co-operate; if the water is permitted to increaſe, and the channels of the different branches are allowed to be augmented, the ſea will continue to ſnatch new lands from the inhabitants, which appears to be the inevitable doom of Egypt, while it continues in the hands of a people who are ignorant and uncultivated.

A large proportion of the land formerly watered by the branches of the Nile, anciently denoted the Peluſiac, Tanitic, and Mendeſian branches, is now the bed of Lake Menzaleh. Lake Bourlos is not far from the mouth of what was formerly called the Sebennitic branch, and Lake Maadieh is near the mouth of the ancient Canopic. Lake Mareotis was at too great a diſtance from the Nile to be filled up with the mud which it depoſits, the waters of which were diverted from the lake, by a canal which had been cut for the conveyance of water to the city of Alexandria; and having no communication with the ſea, its waters of conſequence were gradually evaporated. It ſtill, however, contained a moving ſand and a brackiſh mud, which receiving the rain in winter, and a ſmall portion of the waters from the Nile by the canals of Bahireh, it exhibits the appearance of a marſh during the greater part of the year. There are alſo a few lakes which owe their origin to the redundant waters of the Nile, diffuſing themſelves over hollow places in which they are confined, and only diſappear by the gradual proceſs of evaporation.

In addition to the branches and chief canals already mentioned, there are numerous canals in Lower Egypt by which it is interſected. Theſe convey the waters of the inundation, which dykes in different diſtricts ſerve to retain. By theſe waters the more elevated grounds are fertilized, and other cantons in ſucceſſion, after which they are poured into the lakes, or are loſt in the ſea. The ſwelling of this remarkable river commences about the ſummer ſolſtice, reaching its utmoſt extent in the autumnal equinox; and after appearing for a few days in all its native majeſty, it gradually begins

gins to ſubſide. In point of time there is a difference of fifteen days, and ſometimes twice that period, with reſpect to the riſe and fall of the Nile; but it may be affirmed in general, that Lower Egypt cannot be ſafely paſſed during any more of the year than from the beginning of February to the end of Auguſt. At this time the great branches alone contain water, on which paſſage boats are always to be met with.

It is obvious from this ſuccinct account of the general face of the country, that no invading army could carry on any military operations in Lower Egypt during more than ſeven months in the year. It may perhaps be admitted with truth, that the confines of the deſert might be traverſed during the five remaining months; but the villages in that direction are ill qualified to grant thoſe neceſſary ſupplies to an army which, after croſſing the deſert, muſt be in want of every thing. No communication could be kept open from the deſert with the interior, from September to December incluſive. At this period, therefore, an enemy could not carry on any military operations in the interior but by water. Nor would an army deſtined to defend Egypt find itſelf free from very conſiderable embaraſſment during the continuance of the inundation; for as a conſiderable part of its movements would unavoidably be made on that element, they would be from the nature of things both tedious and difficult.

137
Mr Bruce's account of the deſerts, marble mountains, &c.

Mr Bruce has given us a particular account of the ſources from whence were derived the vaſt quantities of marble met with in the remains of ancient buildings in this country. Theſe he diſcovered during his journey from Kenne to Coſſeir on the Red ſea, before he took his expedition to Abyſſinia. He gives a moſt diſmal idea of the deſerts through which he paſſed. What houſes he met with were conſtructed like thoſe M. Volney mentions, of clay, being no more than ſix feet in diameter, and about ten in height. The mountains were the moſt dreary and barren that can be imagined; and the heat of the ſun ſo great, that two ſticks rubbed together only for half a minute would take fire and flame. In theſe burning regions no living creature was to be met with, even the poiſonous ſerpents and ſcorpions not being able to find ſubſiſtence. The firſt animal he ſaw was a ſpecies of ants in a plain called *Hamra* from the purple colour of its ſand; and it was remarkable that theſe inſects were of the ſame colour with the ſand itſelf. No water was anywhere to be met with on the ſurface; though at a place called *Legeta* there were ſome draw-wells, the water of which was more bitter than ſoot itſelf. At Hamra the porphyry mountains and quarries begin, the ſtone of which is at firſt ſoft and brittle; but the quantity is immenſe, as a whole day was taken up in paſſing by them. Theſe porphyry mountains begin in the latitude of nearly 24 degrees, and continue along the coaſt of the Red ſea to about 22° 30′, when they are ſucceeded by the marble mountains; theſe again by others of alabaſter, and theſe laſt by baſaltic mountains. From the marble mountains our author ſelected twelve kinds, of different colours, which he brought along with him. Some of the mountains appeared to be compoſed entirely of red and others of green marble, and by their different colours afforded an extraordinary ſpectacle. Not far from the porphyry mountains the cold was ſo great, that his camels died on his return from Abyſſinia though the thermometer ſtood no lower than 42 degrees.

Near to Coſſeir he diſcovered the quarries whence the ancients obtained thoſe immenſe quantities of marble with which they conſtructed ſo many wonderful works. The firſt place where the marks of their operations were very perceptible, was a mountain much higher than any they had yet paſſed, and where the ſtone was ſo hard that it did not even yield to the blows of a hammer. In this quarry he obſerved that ſome ducts or channels for conveying water terminated; which, according to him, ſhows that water was one of the means by which theſe hard ſtones were cut. In four days, during which our author travelled among theſe mountains, he ſays, that he had "paſſed more granite, porphyry, marble, and jaſper, than would build Rome, Athens, Corinth, Syracuſe, Memphis, Alexandria, and half a dozen ſuch cities." It appeared to him that the paſſages between the mountains, and which he calls *defiles*, were not natural but artificial openings; where even whole mountains had been cut out, in order to preſerve a gentle ſlope towards the river. This deſcent our author ſuppoſes not to be above one foot in 50; ſo that the carriages muſt have gone very eaſily, and rather required ſomething to retard their velocity than any force to pull them forward. Concerning the mountains in general, he obſerves, that the porphyry is very beautiful to the eye, and is diſcovered by a fine purple ſand without any gloſs. An unvariegated marble of a green colour is generally met with in the ſame mountain; and where the two meet, the marble becomes ſoft for a few inches, but the porphyry retains its hardneſs. The granite has a dirty brown appearance, being covered with ſand; but on removing this, it appears of a gray colour with black ſpots, with a reddiſh caſt all over it. The granite mountains lie nearer to the Red ſea, and ſeem to have afforded the materials for Pompey's pillar. The redneſs above mentioned ſeems to go off on expoſure to the air; but re-appears on working or poliſhing the ſtone farther. The red marble is next to the granite, though not met with in the ſame mountain. There is alſo a red kind with white veins, and vaſt quantities of the common green ſerpentine. Some ſamples of that beautiful marble named *Iſabella* were likewiſe obſerved; one of them of that yellowiſh caſt called *quaker colour*, the other of the blueiſh kind named *dove colour*. The moſt valuable kind is that named *verde antico*, which is found next to the Nile in the mountains of ſerpentine. It is covered by a kind of blue flaky ſtone, ſomewhat lighter than a ſlate, more beautiful than moſt kinds of marble, and when poliſhed having the appearance of a volcanic lava. In theſe quarters the verde antico had been uncovered in patches of about 20 feet ſquare. There were ſmall pieces of African marble ſcattered about in ſeveral places, but no rocks or mountains of it; ſo that our author conjectures it to lie in the heart of ſome other kind. The whole is ſituated on a ridge with a deſcent to the eaſt and weſt; by which means it might eaſily be conveyed either to the Nile, or Red ſea, while the hard gravel and level ground would readily allow the heavieſt carriages to be moved with very little force.

138
Of a ſuppoſed emerald mine.

Travellers have talked of an emerald mine in theſe deſerts; but from the reſearches of Mr Bruce, it does not appear to have any exiſtence. In the Red ſea indeed, in the latitude of $25^{\circ} 3'$, at a ſmall diſtance from the ſouth-weſtern coaſt, there is an iſland called the *Mountain of Emeralds;* but none of theſe precious ſtones are to be met with there. Here, as well as on the continent, there were found many pieces of a green pellucid ſubſtance; but veined, and much ſofter than rock cryſtal, though ſomewhat harder than glaſs. A few yards up the mountain he found three pits, which are ſuppoſed to have been the mines whence the ancients obtained the emeralds; but though many pieces of the green ſubſtance above mentioned were met with about theſe pits, no ſigns of the true emerald could be perceived. This ſubſtance, however, he conjectures to have been the *ſmaragdus* of the Romans. In the mountains of Coſſeir, as well as in ſome places of the deſerts of Nubia, our author found ſome rocks exactly reſembling petrified wood.

139
Stones of a curious appearance.

The only metal ſaid by the ancients to be produced in Egypt is copper. On the road to Suez are found great numbers of thoſe ſtones called *Egyptian flints* and *pebbles*, though the bottom is a hard, calcareous, and ſonorous ſtone. Here alſo M. Volney tells us, that the ſtones above mentioned, and which reſemble petrified wood, are to be met with. Theſe, he ſays, are in the form of ſmall logs cut ſlanting at the ends, and might eaſily be taken for petrifactions, though he is convinced that they are real minerals.

140
Salt lakes.

141
Vegetable mould of Egypt not originally derived from Ethiopia.

F. Sicard mentions two lakes, from the water of which is produced annually a great quantity of ſalt containing much mineral alkali: and M. Volney informs us, that the whole ſoil of this country is impregnated with ſalt; ſo that, upon digging to ſome depth in the ground, we always meet with brackiſh water impregnated in ſome degree with the mineral alkali as well as with common ſalt. The two lakes mentioned by Sicard are ſituated in the deſert to the weſt of the Delta; and are three or four leagues in length, and about a quarter of a league in breadth, with a ſolid and ſtony bottom. For nine months in the year they are without water; but in the winter time there oozes out of the earth a reddiſh violet coloured water, which fills the lakes to the height of five or ſix feet. This being evaporated by the return of the heat, there remains a bed of ſalt two feet thick and very hard, which is broken in pieces with iron bars; and no leſs than 30,000 quintals are procured every year from theſe lakes. So great is the propenſity of the Egyptian ſoil to produce ſalt, that even when the gardens are overflowed for the ſake of watering them, the ſurface of the ground, after the evaporation and abſorption of the water, appears glazed over with ſalt. The water found in the wells contains mineral alkali, marine ſalt, and a little nitre. M. Volney is of opinion, that the fertile mould of Egypt, which is of a blackiſh colour, differs eſſentially from that of the other parts; and is derived from the internal parts of Ethiopia along with the waters of the Nile. This ſeems to contradict what he had before advanced againſt M. Savary concerning the increaſe of the land of Egypt by means of the waters of this river: but there is no reaſon at all to ſuppoſe this kind of earth to be of a foreign origin; it being always the reſult of vegetation and cultivation. Even the moſt barren and ſandy ſpots in the world, if properly watered, and ſuch vegetables planted in them as would grow there, in time would be covered with this black earth as well as others: and of this kind of artificial formation of ſoil, travellers give us a remarkable inſtance in the garden of the monks at Mount Sinai, where the country is naturally as barren as in any place of the world. "The monks of Sinai (ſays Dr Shaw), in a long proceſs of time, have covered over with dung and the ſweepings of their convent near four acres of naked rocks; which produce as good cabbage, roots, ſalad, and all kinds of pot herbs, as any ſoil and climate whatſoever. They have likewiſe raiſed olive, plum, almond, apple, and pear trees, not only in great numbers, but of excellent kinds. The pears particularly are in ſuch eſteem at Cairo, that there is a preſent of them ſent every year to the baſhaw and perſons of the firſt quality. Neither are their grapes inferior in ſize and flavour to any whatſoever: it being fully demonſtrated, by what this little garden produces, how far an indefatigable induſtry can prevail over nature; and that ſeveral places are capable of culture and improvement which were intended by nature to be barren, and which the lazy and ſlothful have always ſuffered to be ſo."

142
Natural fertility of Egypt not diminiſhed.

From this general account of the country, we may reaſonably conclude, that the natural fertility of Egypt is not diminiſhed in modern times, provided the ſame pains were taken in the cultivation of it as formerly; but this is not to be expected from the preſent degenerate race of inhabitants. "The Delta (ſays M. Savary) is at preſent in the moſt favourable ſtate for agriculture. Waſhed on the eaſt and weſt by two rivers formed by the diviſion of the Nile, each of which is as large and more deep than the Loire, interſected by innumerable rivulets; it preſents to the eye an immenſe garden, all the different compartments of which may be eaſily watered. During the three months that the Thebais is under water, the Delta poſſeſſes fields covered with rice, barley, vegetables, and winter fruits. It is alſo the only part of Egypt where the ſame field produces two crops of grain within the year, the one of rice, the other of barley."

143
Method of purifying and cooling the water in Egypt.

The only cauſe of all this fertility is the Nile, without which the whole country would ſoon become an uninhabitable deſert, as rain falls very ſeldom in this part of the world. It flows with a very gentle ſtream through the flat country, and its waters are very muddy, ſo that they muſt have time to ſettle, or even require filtration before they can be drunk. For purifying the water, the Egyptians, according to M. Volney, uſe bitter almonds, with which they rub the veſſel containing it, and then the water becomes light and good; but on what principle this ingredient acts we cannot pretend to determine. Unglazed earthen veſſels filled with water are kept in every apartment; which by a continual evaporation through their porous ſubſtance, render the contained fluid very cool even in the greateſt heats. The river continues muddy for ſix months: and during the three which immediately precede the inundation, the ſtream being reduced to an inconſiderable depth, becomes heated, green, fetid, and full of worms. The Egyptians in former times paid divine honours to the Nile, and ſtill hold it in great veneration. They believe its waters to be very nouriſhing, and that they are ſuperior

rior to any in the world; an opinion very excuſable in them, as they have no other, and large draughts of cold water are among their higheſt luxuries.

144 Of the inundation of the Nile.

This river, ſwelled by the rains which fall in Abyſſinia, begins to riſe in Egypt about the month of May; but the increaſe is inconſiderable till towards the end of June, when it is proclaimed by a public crier through the ſtreets of Cairo. About this time it has uſually riſen five or ſix cubits; and when it has riſen to 16, great rejoicings are made, and the people cry out *Waſſah Allah*, that is, that God has given them abundance. This commonly takes place about the latter end of July, or at fartheſt before the 20th of Auguſt; and the ſooner it takes place, ſo much the greater are the hopes of a good crop. Sometimes, though rarely, the neceſſary increaſe does not take place till later. In the year 1705, it did not ſwell to 16 cubits till the 19th of September; the conſequence of which was that the country was depopulated by famine and peſtilence.

We may eaſily imagine that the Nile cannot overflow the whole country of itſelf in ſuch a manner as to render it fertile; for which reaſon there are innumerable canals cut from it acroſs the country, it has already been obſerved, by which the water is conveyed to diſtant places, and almoſt every town or village has one of theſe canals. In thoſe parts of the country where the inundation does not reach, and where more water is required than it can furniſh, as for watering of gardens, they muſt have recourſe to artificial means for raiſing it from the river. In former times they made uſe of Archimedes's ſcrew; but that is now diſuſed, and in place of it they have choſen the Perſian wheel. This is a large wheel turned by oxen, having a rope hung with ſeveral buckets which fill as it goes round, and empty themſelves into a ciſtern at the top. Where the banks of the river are high, they frequently make a baſon in the ſide of them, near which they fix an upright pole, and another with an axle acroſs the top of that, at one end of which they hang a great ſtone, and at the other a leathern bucket; this bucket being drawn down into the river by two men, is raiſed by the deſcent of the ſtone, and emptied into a ciſtern placed at a proper height. This kind of machine is uſed chiefly in the upper parts of the country, where the raiſing of water is more difficult than in places near the ſea. When any of the gardens or plantations want water, it is conveyed from the ciſterns into little trenches, and from thence conducted all round the beds in various rills, which the gardener eaſily ſtops by raiſing the mould againſt them with his foot, and diverts the current another way as he ſees occaſion.

145 Nilometer deſcribed.

The riſe of the inundation is meaſured, as has already been obſerved, by an inſtrument adapted for the purpoſe, and called *mikeas*, which we tranſlate *nilometer*. Mr Bruce informs us, that this is placed between Geeza and Cairo, on the point of an iſland named *Rhoda*, about the middle of the river, but ſomewhat nearer to Geeza. It is a round tower with an apartment, in the middle of which is a ciſtern neatly lined with marble. The bottom of this ciſtern reaches to that of the river, and there is a large opening by which the water has free acceſs to the inſide. The riſe of the water is indicated by an octagonal column of blue and white marble, on which are marked 20 peeks or cubits of 22 inches each. The two lowermoſt of theſe have no ſubdiviſions; but each of the reſt is divided into 24 parts called *digits;* the whole height of the pillar being 36 feet 8 inches.

146 Of the canals by which the water is conveyed, &c.

When the river has attained its proper height, all the canals are opened, and the whole country laid under water. During the time of the inundation a certain vortical motion of the waters takes place: but notwithſtanding this, the Nile is ſo eaſily managed, that many fields lower than the ſurface of its waters are preſerved from injury merely by a dam of moiſtened earth not more than eight or ten inches in thickneſs. This method is made uſe of particularly in the Delta when it is threatened with a flood.

As the Nile does not always riſe to a height ſufficient for the purpoſes of agriculture, the former ſovereigns of Egypt were at vaſt pains to cut proper canals in order to ſupply the deficiency. Some of theſe are ſtill preſerved, but great numbers are rendered uſeleſs through the indolence or barbarity of their ſucceſſors. Thoſe which convey the water to Cairo, into the province of Fayoom, and to Alexandria, are beſt taken care of by government. The laſt is watched by an officer appointed for that purpoſe, whoſe office it is to hinder the Arabs of Bachria, who receive this ſuperfluous water, from turning it off before Alexandria be provided for, or opening it before the proper time, which would hinder the increaſe of the river. In like manner, that which conveys the water to Fayoom is watched, and cannot be opened before that of Cairo, which is called the *Canal of Trajan*. A number of other canals, only taken care of by thoſe who derive advantage from them, proceed from that arm of the Nile which runs to Damietta, and fertilize the province of Sharkia; which, making part of the iſthmus of Suez, is the moſt conſiderable of Egypt, and the moſt capable of a great increaſe of cultivation. The plains of Gaza which lie beyond, and are poſſeſſed by the Arabs, would be no leſs fertile, were it not for the exceſſive inclination theſe people have to deſtroy, ſo that they make war even with the ſpontaneous productions of the earth. A number of other canals run through the Delta; and the veſtiges of thoſe which watered the provinces to the eaſtward and weſtward, ſhow that in former times theſe were the beſt cultivated parts of Egypt. "We may alſo preſume (ſays the baron de Tott), from the extent of the ruins of Alexandria, the conſtruction of the canal, and the natural level of the lands which encompaſs the lake Mareotis, and extend themſelves weſtward to the kingdom of Barca, that this country, at preſent given up to the Arabs, and almoſt deſert, was once ſufficiently rich in productions of every kind to furniſh the city of Alexander with its whole ſubſiſtence."

147 Air and climate of Egypt.

The air and climate of Egypt are extremely hot, not only from the height of the ſun, which in ſummer approaches to the zenith, but from the want of rain and from the vicinity of thoſe burning and ſandy deſerts which lie to the ſouthward. In the months of July and Auguſt, according to M. Volney, Reaumur's thermometer ſtands, even in the moſt temperate apartments, at the height of 24 or 25 degrees above the freezing point; and in the ſouthern parts it is ſaid to riſe ſtill higher. Hence, he ſays, only two ſeaſons ſhould be diſtinguiſhed in Egypt, the cool and the hot, or ſpring and ſummer. The latter continues for the greateſt part of the year, viz. from March to November or even longer; for by the end of February the ſun is intolerable to a European at nine o'clock in the morning. During the whole of this ſeaſon, the air ſeems to be inflamed, the ſky ſparkles, and every one ſweats profuſely, even without the leaſt exerciſe, and when covered with the lighteſt dreſs. This heat is tempered by the inundation of the Nile, the fall of the night dews, and the ſubſequent evaporation; ſo that ſome of the European merchants, as well as the natives, complain of the cold in winter. The dew we ſpeak of does not fall regularly throughout the ſummer, as with us; the parched ſtate of the country not affording a ſufficient quantity of vapour for this purpoſe. It is firſt obſerved about St John's day (June 24th), when the river has begun to ſwell, and conſequently a great quantity of water is raiſed from it by the heat of the ſun, which being ſoon condenſed by the cold of the night air, falls down in copious dews.

It might naturally be imagined, that as for three months in the year Egypt is in a wet and marſhy ſituation, the exceſſive evaporation and putrefaction of the ſtagnating waters would render it very unhealthy. But this is by no means the caſe. The great dryneſs of the air makes it abſorb vapours of all kinds with the utmoſt avidity; and theſe riſing to a great height, are carried off by the winds either to the ſouthward or northward, without having time to communicate any of their pernicious effects. This dryneſs is ſo remarkable in the internal parts of the country, that fleſh meat expoſed to the open air does not putrefy even in ſummer, but ſoon becomes hard and dry like wood. In the deſerts there are frequently dead carcaſes thus dried in ſuch a manner, and become ſo light, that one may eaſily lift that of a camel with one hand. In the maritime parts, however, this dryneſs of the air is not to be expected. They diſcover the ſame degree of moiſture which uſually attends ſuch ſituations. At Roſetta and Alexandria, iron cannot be expoſed to the air for 24 hours without ruſting. According to M. Volney, the air of Egypt is alſo ſtrongly impregnated with ſalts: for which opinion he gives the following reaſon: "The ſtones are corroded by natrum (mineral alkali or ſoda), and in moiſt places long cryſtallizations of it are to be found, which might be taken for ſaltpetre. The wall of the Jeſuits garden at Cairo, built with earth and bricks, is everywhere covered with a cruſt of this natrum as thick as a crown piece: and when this garden has been overflowed by the waters of the kalidj (canal), the ground, after they have drained off, appears ſparkling on every ſide with cryſtals, which certainly were not brought thither by the water, as it ſhows no ſign of ſalt either to the taſte or by diſtillation."—But whatever may be the quantity of ſalt contained in the earth, it is certain that M. Volney's opinion of its coming thither from the air cannot be juſt. The ſalt in queſtion is exceſſively fixed, and cannot be diſſipated into the air without the violent heat of a glaſshouſe furnace; and even after this has been done, it will not remain diffuſed through the atmoſphere, but quickly falls back again. No experiments have ever ſhown that any ſalt was or could be diffuſed in the air, except volatile alkali, and this is now known to be formed by the union of two permanently elaſtic fluids; and it is certain that a ſaline air would quickly prove fatal to the animals who breathed it. The abundance of this kind of ſalt in Egypt therefore only ſhows, that by ſome unknown operation the heat of the ſun forms it from the two ingredients of earth and water, though we do not yet underſtand the manner, nor are able to imitate this natural operation.

148
Why exotic plants will not thrive in Egypt.

To this ſaline property of the earth M. Volney aſcribes the exceſſive quickneſs of vegetation in Egypt, which is ſo great, that a ſpecies of gourd called *kara* will, in 24 hours, ſend forth ſhoots of four inches in length; but for the ſame reaſon, in all probability, it is that no exotic plant will thrive in Egypt. The merchants are obliged annually to ſend to Malta for their garden ſeeds; for though the plants thrive very well at firſt, yet if the ſeed of them is preſerved, and ſown a ſecond year, they always come up too tall and ſlender.

149
Cauſe of the dews in Egypt.

By reaſon of the great dryneſs of the air, Egypt is exempted from the phenomena of rain, hail, ſnow, thunder, and lightning. Earthquakes are alſo ſeldom heard of in this country; though ſometimes they have been very fatal and deſtructive, particularly one in the year 1112. In the Delta, it never rains in ſummer, and very ſeldom at any other time. In 1761, however, ſuch a quantity of rain unexpectedly fell, that a great number of houſes, built with mudwalls, tumbled entirely down by being ſoaked with the water, to which they were unaccuſtomed. In the Higher Egypt the rain is ſtill leſs frequent; but the people, ſenſible of the advantages which accrue from it, always rejoice when any falls, however inſufficient to anſwer the purpoſe. This deficiency of rain is ſupplied by the inundation and dews already mentioned. The latter proceed, as has already been ſaid, partly from the waters of the inundation and partly from the ſea. At Alexandria, after ſunſet, in the month of April, the clothes expoſed to the air on the terraces are ſoaked with them as if it had rained. Theſe dews are more or leſs copious according to the direction of the wind. They are produced in the greateſt quantity by the weſterly and northerly winds, which blow from the ſea; but the ſouth and ſouth-eaſt winds, blowing over the deſerts of Africa and Arabia, produce none.

150
Remarkable regularity of the winds.

The periodical return of winds from a certain quarter is a very remarkable phenomenon in this country. When the ſun approaches the tropic of Cancer, they ſhift from the eaſt to the north; and, during the month of June, they always blow from the north or north-weſt. They continue northerly all the month of July, varying only ſometimes towards the eaſt, and ſometimes the contrary way. About the end of this month, and during the whole of Auguſt and September, they blow directly from the north, and are but of a moderate ſtrength, though ſomewhat weaker in the night than in the day. Towards the end of September they return to the eaſt, though they do not abſolutely fix on that point, but blow more regularly from it than any other except the north. As the ſun approaches the ſouthern tropic, they become more variable and tempeſtuous, blowing moſt commonly from the north, north-eaſt, and weſt, which they continue to do throughout the months of December, January, and February; and, during that ſeaſon, the vapours raiſed from the Mediterranean condenſe into miſt, or even ſometimes into rain. Towards the end of February, and in the ſucceeding month, they more frequently blow from the ſouth than from any other quarter. During ſome part of the month of March and in that of April, they blow from the ſouth, ſouth-eaſt, and ſouth-weſt; ſometimes from the north and eaſt, the latter becoming moſt prevalent about the end of that month, and continuing during the whole of May.

151
Rains in Abyſſinia and in Armenia occaſioned by two oppoſite currents of air.

It is to the long continuance of the north winds, formerly called the *Eteſian winds*, that Egypt probably owes its extreme dryneſs, as well as part of the inundation by which it is fertilized. From the month of April to July, there appear to be two immenſe currents in the atmoſphere, the under one blowing from the north, and the upper from the ſouth. By the former the vapours are raiſed from the Mediterranean and ſouthern parts of Europe, where they are carried over Abyſſinia, diſſolving there in immenſe deluges of rain; while by the latter the ſuperfluous vapours, or thoſe raiſed from the country of Abyſſinia itſelf, are carried northward toward the ſources of the Euphrates. Here the clouds coming from the ſouth, deſcending into the lower part of the atmoſphere, diſſolve in like manner into rain, and produce an inundation of the Euphrates ſimilar to that of the Nile, and immediately ſucceeding it. Mr Bruce had an opportunity of aſcertaining this fact in the month of June 1768; for at that time, while on a voyage from Sidon to Alexandria, he obſerved great numbers of thin white clouds moving rapidly from the ſouth, and in direct oppoſition to the Eteſian winds.

152
Of the hot winds.

Beſides the ordinary winds here ſpoken of, Egypt is infeſted with the deſtructive blaſts common to all warm countries which have deſerts in their neighbourhood. Theſe have been diſtinguiſhed by various names, ſuch as *poiſonous winds*, *hot winds of the deſert*, *Samiel*, *the wind of Damaſcus*, *Kamſin*, and *Simoom*. In Egypt they are denominated "winds of 50 days," becauſe they moſt commonly prevail during the 50 days preceding and following the equinox; though, ſhould they blow conſtantly during one half of that time, an univerſal deſtruction would be the conſequence. Of theſe travellers have given various deſcriptions. M. Volney ſays, that the violence of their heat may be compared to that of a large oven at the moment of drawing out the bread. They always blow from the ſouth; and are undoubtedly owing to the motion of the atmoſphere over ſuch vaſt tracts of hot ſand, where it cannot be ſupplied by a ſufficient quantity of moiſture. When they begin to blow, the ſky loſes its uſual ſerenity, and aſſumes a dark, heavy, and alarming aſpect, the ſun himſelf laying aſide his uſual ſplendor, and becoming of a violet colour. This terrific appearance ſeems not to be occaſioned by any real haze or cloud in the atmoſphere at that time, but ſolely to the vaſt quantity of fine ſand carried along by thoſe winds, and which is ſo exceſſively ſubtile that it penetrates everywhere. The motion of this wind is always rapid, but its heat is not intolerable till after it has continued for ſome time. Its pernicious qualities are evidently occaſioned by its exceſſive avidity of moiſture. Thus it dries and ſhrivels up the ſkin; and by doing the ſame to the lungs, will in a ſhort time produce ſuffocation and death. The danger is greateſt to thoſe of a plethoric habit of body, or who have been exhauſted by fatigue; and putrefaction ſoon takes place in the bodies of ſuch as are deſtroyed by it. Its extreme dryneſs is ſuch, that water ſprinkled on the floor evaporates in a few minutes; all the plants are withered and ſtripped of their leaves; and a fever is inſtantly produced in the human ſpecies by the ſuppreſſion of perſpiration. It uſually laſts three days, but is altogether inſupportable if it continue beyond that time. The danger is greateſt when the wind blows in ſqualls, and to travellers who happen to be expoſed to its fury without any ſhelter. The beſt method in this caſe is to ſtop the noſe and mouth with an handkerchief. Camels, by a natural inſtinct, bury their noſes in the ſand, and keep them there till the ſquall is over. The inhabitants, who have an opportunity of retiring to their houſes, inſtantly ſhut themſelves up in them, or go into pits made in the earth, till the deſtructive blaſt be over.

The deſcription of a blaſt of this kind which overtook Mr Bruce in the deſert of Nubia is ſtill more terrible than that juſt given from M. Volney. We have already mentioned ſomething of the pillars of moving ſand raiſed by the winds in the deſert. Theſe were obſerved by our traveller on this occaſion in all their terrific majeſty. Sometimes they appeared to move ſlowly; at other times with incredible ſwiftneſs, ſo that they could not have been avoided by the fleeteſt horſe. Sometimes they came ſo near, that they threatened deſtruction to the whole company. Frequently the tops, when arrived at an immenſe height, ſo that they were loſt in the clouds, ſuddenly ſeparated from the bodies, and diſperſed themſelves in the air; and ſometimes the whole column broke off near the middle, as if it had received a cannon ſhot; and their ſize was ſuch, that at the diſtance of about three miles, they appeared ten feet in diameter. Next day they appeared of a ſmaller ſize, but more numerous, and ſometimes approached within two miles of the company. The ſun was now obſcured by them, and the tranſmiſſion of his rays gave them a dreadful appearance reſembling pillars of fire. This was pronounced by the guide to be a ſign of the approaching *Simoom* or hot wind; and he directed, that when it came, the people ſhould fall upon their faces and keep their mouths on the ſand, to avoid the drawing in this pernicious blaſt with their breath. On his calling out that the Simoom was coming, Mr Bruce turned for a moment to the quarter from whence it came, which was the ſouth-eaſt. It appeared like a haze or fog of a purple colour, but leſs bright than the purple part of the rainbow; ſeemingly about 20 yards in breadth, and about 12 feet high from the ground. It moved with ſuch rapidity, that before he could turn about and fall upon his face, he felt the vehement heat of its current upon his face; and even after it paſſed over, which was very quickly, the air which followed was of ſuch a heat as to threaten ſuffocation. Mr Bruce had unfortunately inſpired ſome part of the pernicious blaſt; by which means he almoſt entirely loſt his voice, and became ſubject to an aſthmatic complaint, from which he did not get free for two years. The ſame phenomenon occurred twice more on their journey through this deſert. The ſecond time, it came from the ſouth a little to the eaſt: but it now ſeemed to have a ſhade of blue along with the purple, and its edges were leſs perfectly defined; reſembling rather a thin ſmoke, and having

ving about a yard in the middle tinged with blue and purple. The third time, it was preceded by an appearance of ſandy pillars more magnificent than any they had yet obſerved; the ſun ſhining through them in ſuch a manner as to give thoſe which were neareſt a reſemblance of being ſpangled with ſtars of gold. The ſimoom which followed had the ſame blue and purple appearance as before, and was followed by a moſt ſuffocating wind for two hours, which reduced our travellers to the loweſt degree of weakneſs and deſpondency. It was remarkable that this wind always came from the ſouth-eaſt, while the ſandy pillars, which prognoſticated its approach, affected to keep to the weſtward, and to occupy the vaſt circular ſpace incloſed by the Nile to the weſt of their route, going round by Chagre towards Dongola. The heaps of ſand left by them when they fell, or raiſed by the whirlwinds which carried them up, were 12 or 13 feet high, exactly conical, tapering to a fine point, and their baſes well proportioned.

153
Of the inhabitants of Egypt.

The inhabitants of Egypt may now be diſtinguiſhed into four diſtinct races of people.

I. The *Arabs*, who may be ſubdivided into three claſſes. 1. The poſterity of thoſe who ſettled here immediately after the conqueſt of the country by Amrou Ebn Al As, the khalif Omar's general. 2. The *Magrebians*, or Weſtern Arabs, who at different times have migrated from the countries to the weſtward of Egypt, and are deſcended from the Saracen conquerors of Mauritania. 3. The *Bedouins*, or Arabs of the deſert, known to the ancients by the name of *Scenites*, or dwellers in tents. The firſt of theſe claſſes are now found among the huſbandmen and artizans; and are diſtinguiſhed from the others by being of a more robuſt habit of body, as well as of a larger ſtature than the others. They are in general five feet four inches high; and many of them attain two or three inches more, and are muſcular without being fleſhy. Their countenances are almoſt black, but their features are not diſagreeable; and as thoſe of the country do not ally themſelves in marriage but with the people of their own tribe, their faces have all a ſtrong reſemblance to each other. This is not the caſe with ſuch as live in towns, by reaſon of their promiſcuous marriages. The ſecond claſs are more numerous in the Said, where they have villages and even diſtinct ſovereigns of their own. Like the former, they apply themſelves to agriculture and mechanical occupations. The Bedouins paſs their lives among the rocks, ruins, and ſequeſtrated places where they can find water; ſometimes uniting in tribes and living in low ſmoky tents, and ſhifting their habitations from the deſert to the banks of the river and back again, as beſt ſuits their conveniency. Their time of inhabiting the deſert is the ſpring; but after the inundation they take up their reſidence in Egypt, in order to profit by the fertility of the country. Some farm lands in the country, which they cultivate, but change annually. In general, all theſe Bedouins are robbers, and are a great terror to travellers as well as to the huſbandmen; but though their number is eſtimated at not leſs than 30,000, they are diſperſed in ſuch a manner that they cannot attempt any thing of conſequence.

II. The *Copts* are deſcendants of thoſe inhabitants of Egypt whom the Arabs ſubdued, and who were compoſed of original Egyptians, Perſians and Greeks. M. Volney is of opinion that their name of Copts is only an abbreviation of the Greek word *Aigouptios*, an Egyptian. They are principally to be met with in the Said, though ſome alſo inhabit the Delta. They have all a yellowiſh duſky complexion, puffed-up viſage, ſwoln eyes, flat noſes, and thick lips; and in fact the exact countenance of a mulatto. M. Volney, from a view of the ſphynx, and finding its features to be ſuch as is juſt now deſcribed, concludes, that the ancient Egyptians were real negroes; which he thinks is likewiſe confirmed by a paſſage in Herodotus, where he concludes, that the inhabitants of Colchis were deſcended from the Egyptians, "on account of the blackneſs of their ſkins and frizzled hair." M. Volney alſo remarks, that the countenance of the negroes is ſuch as exactly repreſents that ſtate of contraction aſſumed by our faces when ſtrongly affected by heat. The eye-brows are knit, the cheeks riſe, the eye-lids are contracted, and the mouth diſtorted; and this ſtate of contraction to which the features of the negroes are perpetually expoſed in the hot climates they inhabit, is become particularly characteriſtic. Exceſſive cold and ſnow produces the ſame effect; and hence this kind of countenance is alſo common among the Tartars; while, in the temperate climates, the features are proportionably lengthened, and the whole countenance expanded.

The Copts profeſs the Chriſtian religion, but follow the hereſy of the Eutychians, whence they have been perſecuted by the Greeks; but having at laſt got the better of their adverſaries, they are become the depoſitaries of the regiſters of the lands and tribes. At Cairo they are called *writers*; and are the intendants, ſecretaries, and collectors for government. The head of their claſs is writer to the principal chief; but they are all hated by the Turks, to whom they are ſlaves, as well as by the peaſants whom they oppreſs. Their language bears a great reſemblance to the Greek; but they have five letters in their alphabet, as well as a number of words in their language, which may be conſidered as the remains of the ancient Egyptian. Theſe are found to bear a near reſemblance to the dialects of ſome of the neighbouring nations, as the Arabic, Ethiopian, Syriac, &c. and even of thoſe who lived on the banks of the Euphrates. The language of the Copts, however, has fallen into diſuſe for upwards of 300 years. On the conqueſt of the country by the Saracens, the latter obliged the people to learn their language; and about the year 722 the uſe of the Greek tongue was prohibited throughout the whole of their empire: the Arabic language then of courſe became univerſal; while the others, being only met with in books, ſoon became totally neglected. The true Coptic, therefore, though there is a tranſlation of the ſcriptures and many books of devotion written in it, is underſtood by nobody, not even the monks and prieſts.

III. The *Turks*, who have the title of being maſters of Egypt, but are chiefly to be met with at Cairo, where they poſſeſs the religious and military employments. Formerly they poſſeſſed alſo the poſts under government; but theſe are now occupied by the fourth race of inhabitants, viz.

IV. The *Mamlouks*. Of the origin of theſe we have already given ſome account: we have only, therefore, to relate ſome of the moſt remarkable particulars concerning their conſtitution and government, manners, &c.

Theſe people, as has already been mentioned, are the real maſters of Egypt; and in order to ſecure themſelves in the poſſeſſion of the country, they have taken ſeveral precautions. One of the principal of theſe is the degradation of the two military corps of azabs and janizaries, both of which were formerly very formidable. They have been able to effect this only in conſequence of the corrupt and wretched government of the Turks; for before the revolt of Ibrahim Kiaya, the Turkiſh troops, which ought to have conſiſted of 40,000, were reduced to leſs than half that number through the avarice and malverſation of their officers. Their degradation was completed by Ali Bey; who having firſt diſplaced all the officers who gave him any umbrage, left their places vacant, acd ſo reduced the conſequence of the whole, that the azabs and janizaries are now only a rabble of vagabonds, who dread the Mamlouks as much as the meaneſt of the populace. The principal body of the Mamlouks reſide at Cairo; but many of them are diſperſed through the country, in order to keep up their authority, collect the tribute, and oppreſs the people: yet it ſhould ſeem very eaſy for the Porte to diſpoſſeſs them of this uſurped authority, as their number is ſuppoſed not to exceed 8500, including among theſe a great many youth under 20 years of age.

154
Abſurd dreſs and accoutrements of the Mamlouks.

The Mamlouks are all horſemen; and as war is accounted the only honourable employment among them, it is reckoned diſgraceful to walk on foot, none but cavalry being accounted ſoldiers. The other inhabitants are allowed only the uſe of mules and aſſes; and the ſame mark of indignity is impoſed upon Europeans; though by proper management and liberal preſents, this may be got over. In the year 1776 Lord Algernoun Percy, afterwards Lord Louvaine, and the earl of Charlemount, obtained permiſſion to ride upon horſeback. The Mamlouks, however, are not incited to this continual appearance on horſeback merely by their ſuppoſed ſuperiority to the reſt of the inhabitants; it is rendered neceſſary by their dreſs, which is extremely unwieldy and cumberſome. It conſiſts of a wide ſhirt of thin yellowiſh-coloured cotton; over which is a gown of Indian linen, or ſome of the light ſtuffs of Damaſcus or Aleppo. Over this is a ſecond covering of the ſame form and wideneſs, with ſleeves reaching down to the ends of the fingers. The former covering is called *antari*, and the latter *caftan*. The caftan is uſually made of ſilk or ſome finer ſtuff than the under garments; and both of them are faſtened by a long belt, which divides the whole dreſs into two bundles. Over all theſe they have a third, named *djouha*, conſiſting of cloth without lining, and made nearly ſimilar to the others, but that the ſleeves are cut in the elbow. This coat is lined, ſometimes even in ſummer, with fur; and as if all this was not ſufficient, they have an outer covering called the *beniche*, which is the cloak or robe of ceremony; and ſo completely covers the body, that even the ends of the fingers are not to be ſeen. Thus, when the beniche and other accoutrements are on, the whole body appears like a long ſack, with a bare neck and bald head covered with a turban thruſt out of it. This turban is called a *kaouk*; and is of a cylindrical form, yellow, and turned up on the outſide with a roll of muſlin artificially folded up. On their feet they have a ſock of yellow leather reaching up to the heels, ſlippers without any quarters, which conſequently are always ready to be left behind in walking. Laſtly, to complete this extraordinary dreſs, they have a kind of pantaloon or trowſers, long enough to reach up to the chin, and ſo large that each of the legs is big enough to contain the whole body; but that they may walk more at their eaſe under ſuch a number of impediments, they tie all the looſe parts of their dreſs with a running ſaſh. "Thus ſwaddled (ſays M. Volney), we may imagine the Mamlouks are not very active walkers; and thoſe who are not acquainted by experience with the prejudices of different countries, will find it ſcarcely poſſible to believe that they look on this dreſs as exceedingly commodious. In vain we may object that it hinders them from walking and encumbers them unneceſſarily on horſeback; and that in battle a horſeman once diſmounted is a loſt man. They reply, *It is the cuſtom*, and every objection is anſwered."

In the accoutrements of their horſes, the Mamlouks are almoſt equally abſurd. The ſaddle is a clumſy piece of furniture, weighing with the ſaddle-cloths not leſs than 25 pounds; while the weight of the ſtirrups is never leſs than 9 or 10 pounds, nay, frequently exceeds 13. On the back-part of the ſaddle riſes a truſſequin about eight inches in height, while a pummel before projects four or five inches, in ſuch a manner as to endanger the breaſt of the horſemen if he ſhould happen to ſtoop. Inſtead of a ſtuffed frame, they have three thick woollen coverings below the ſaddle; the whole being faſtened by a ſurcingle, which, inſtead of a buckle, is tied with leather thongs in very complicated knots, and liable to ſlip. Inſtead of a crupper they have a large martingale which throws them upon the horſes ſhoulders. The ſtirrups are made of copper, longer and wider than the foot, having circular edges an inch high in the middle, and gradually declining toward each end. The edges are ſharp, and uſed inſtead of ſpurs, by which means the poor animal's ſides are much wounded. The weight of the furniture has already been mentioned; and is the more ridiculous as the Egyptian horſes are very ſmall. The bridle is equally ill contrived, and greatly injures the horſe's mouth, eſpecially by reaſon of the violent method they have of managing the animal. Their uſual way is to put the horſe to a full gallop, and ſuddenly ſtop him when at full ſpeed. Thus checked by the bit, he bends in his hind legs, ſtiffens the fore ones, and moves along as if he ſcarce had joints in his body: yet, notwithſtanding all thoſe diſadvantages, our author acknowledges that they are vigorous horſemen, having a martial appearance which pleaſes even ſtrangers.

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Their arms education, &c.

In the choice of their arms they have ſhown themſelves more judicious. Their principal weapon is an Engliſh carbine about 30 inches long; but ſo large in the bore, that it can diſcharge 10 or 12 balls at a time, which can ſcarcely fail of doing great execution even from the moſt unſkilful hand. Beſides two large piſtols carried in the belt, they have ſometimes a heavy mace at the bow of the ſaddle for knocking down their enemy; and by the ſhoulder belt they ſuſpend a crooked ſabre meaſuring 24 inches in a ſtraight line from the

hilt

hilt to the point, but 30 at leaſt in the curve. The reaſon of the preference given to the crooked blade is, that the effect of a ſtraight one depends merely on the force with which it falls, and is confined to a ſmall ſpace, but that of a crooked one is continued longer by the action of the arm in retiring. The Mamlouks commonly procure their ſabres from Conſtantinople, or other parts of Europe; but the beys rival each other in thoſe of Perſia and ſuch as are fabricated of the ancient ſteel of Damaſcus. For theſe they frequently pay as high as 40l. or 50l. ſterling; but though it muſt be allowed that the edge of theſe weapons is exquiſitely keen, yet they have the defect of being almoſt as brittle as glaſs. The whole education and employment of the Mamlouks conſiſts in the exerciſe of theſe weapons, or what is conducive to it; ſo that we ſhould imagine they might at laſt become altogether irreſiſtible. Every morning the greater part of them exerciſe themſelves in a plain near Cairo, by firing their carbines and piſtols in the moſt expeditious manner, having an earthen veſſel for a mark to ſhoot at; and the perſon who breaks it is highly applauded by the beys who attend in order to encourage them. Here alſo they exerciſe themſelves in the uſe of the ſabre, as well as of the bow and arrows; though they do not any longer make uſe of theſe laſt in their engagements. Their favourite diverſion is throwing the *djerid;* a word properly ſignifying a reed, but which is generally made uſe of to ſignify any ſtaff thrown by the hand after the manner of the Roman pilum. In this exerciſe they make uſe of the branches of the palm-tree freſh ſtripped. Theſe branches, which have the form of the ſtalk of an artichoke, are about four feet long, and weigh five or ſix pounds. With theſe the cavaliers enter the liſts, riding full ſpeed, and throwing them afterwards at each other from a conſiderable diſtance. As ſoon as the aſſailant has thrown his weapon, he turns his horſe, and his antagoniſt purſues in his turn. The diverſion, however, frequently turns out very ſerious, as ſome are capable of throwing theſe weapons with force ſufficient to wound their antagoniſts mortally. Ali Bey was particularly dexterous at this kind of ſport, and frequently killed thoſe who oppoſed him. All theſe military exerciſes, however, are by no means ſufficient to render the Mamlouks formidable in the field. In their engagements they have neither order, diſcipline, nor even ſubordination; ſo that their wars are only ſcenes of robbery, plunder, and tumultuary encounters, which begin very often ſuddenly in the ſtreets of Cairo without the leaſt warning. If the contention happens to be transferred to the country, it is ſtill carried on in the ſame manner. The ſtrongeſt or moſt daring party purſues the other. If they are equal in courage, they will perhaps appoint a field of battle, and that without the leaſt regard to advantages of ſituation, but fighting in platoons, with the boldeſt champions at the head of each. After mutual defiances, the attack begins, and every one chooſes out his man. After diſcharging their fire-arms, if they have an opportunity they attack with their ſabres; and ſuch as happen to be diſmounted are helped up again by their ſervants; but if nobody happens to be near, the ſervants will frequently kill them for the ſake of the money they carry about them. Of late, however, the ordinary Mamlouks, who are all ſlaves to the reſt, ſeem convinced that their patrons are the perſons principally intereſted; for which reaſon they reaſonably enough conclude that they ought to encounter the greateſt dangers. Hence they generally leave them to carry on the diſpute by themſelves; and being always ſure of finding a maſter who will employ them, they generally return quietly to Cairo until ſome new revolution takes place.

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Are not formidable in war.

157
Their expenſive way of living.

The mode of living among the Mamlouks is exceedingly expenſive, as may eaſily be conceived from what has already been related. There is not one of them who does not coſt above 100l. ſterling annually, and many of them upwards of 200l. At every return of the faſt of Ramadan, their maſters muſt give them a new ſuit of French and Venetian clothes, with ſtuffs from India and Damaſcus. Frequently they require new horſes and harneſs: they muſt likewiſe have piſtols and ſabres from Damaſcus, with gilt ſtirrups, and ſaddles and bridles plated with ſilver. The chiefs are diſtinguiſhed from the vulgar by the trinkets and precious ſtones they wear; by riding Arabian horſes of 200l. or 300l. value, wearing ſhawls of Caſhmire in value from 25l. to 50l. each, with a variety of peliſſes, the cheapeſt of which coſts above 20l. Even the European merchants have given into this kind of extravagance; ſo that not one of them looks upon his wardrobe to be decently furniſhed unleſs it be in value 500l. or 600l.

158
Their bad character.

Anciently it was cuſtomary for the women to adorn their heads with ſequins; but this is now rejected as not ſufficiently expenſive. Inſtead of theſe, diamonds, emeralds, and rubies, are now ſubſtituted; and to theſe they add French ſtuffs and laces. In other reſpects the character of the Mamlouks is almoſt the worſt that can be imagined. Without affection, tie, or connection with each other or with the reſt of mankind, they give themſelves up without controul to the moſt enormous vices; and, according to M. Volney, they are at once ferocious, perfidious, ſeditious, baſe, deceitful, and corrupted by every ſpecies of debauchery, not excepting even the unnatural vice; of which he tells us not one is free, this being the very firſt leſſon each of them receives from his maſter, all being originally ſlaves, as has already been mentioned.

159
Miſerable ſtate of the Egyptians.

As theſe are the preſent governors of Egypt, we may eaſily judge that the condition of the common people cannot be very agreeable. The greater part of the lands indeed are in the hands of the Mamlouks, beys, and profeſſors of the law, the property of all others being very precarious. Contributions are to be paid, or damages repaired, every moment; and there is neither right of ſucceſſion nor inheritance for real property, but every thing muſt be purchaſed from government. The peaſants are allowed nothing but what is barely ſufficient to ſuſtain life. They cultivate rice and corn indeed, but are not at liberty to uſe either. The only food allowed them is dora or Indian millet, from which they make a kind of taſteleſs bread; and of this, with water and raw onions, conſiſts all their fare throughout the year. They eſteem themſelves happy, therefore, if along with theſe they can ſometimes procure a little honey, cheeſe, ſour milk, or a few dates. They are very fond of fleſh meat and fat; neither of which, however, they have an opportunity of taſting except at extraordinary feſtivals. Their ordinary

dinary dreſs conſiſts of a ſhirt of coarſe blue linen, and a clumſy black cloak; with a ſort of black bonnet over their heads; and over all they wear a long red woollen handkerchief. Their arms, legs, and breaſts, are naked, and moſt of them do not even wear drawers. They live in mud-walled huts of the moſt miſerable conſtruction, where they are expoſed to the inconveniences of ſmoke, heat, and unwholeſome air; to all which are to be added the continual fears they live in of being robbed by the Arabs, oppreſſed by the Mamlouks, or ſome other grievous calamity. The only converſation is concerning the inteſtine troubles and miſery of the country, murders, baſtinadoes, and executions. Here ſentence of death is executed without the leaſt delay or form of trial. The officers who go the rounds in the ſtreets either by night or day, are attended by executioners, who carry along with them leathern bags for receiving the heads they cut off in theſe expeditions. Even the appearance of guilt is not neceſſary to infer a capital puniſhment; for frequently nothing more is requiſite than the poſſeſſion of wealth, or being ſuppoſed to poſſeſs it. In this caſe the unfortunate perſon is ſummoned before ſome bey; and when he makes his appearance, a ſum of money is demanded of him. If he denies that he poſſeſſes it, he is thrown on his back, and receives two or three hundred blows on the ſoles of the feet, nay perhaps is put to death without any ceremony. The only ſecurity of thoſe who poſſeſs any wealth in this country therefore is, to preſerve as great an appearance of poverty as poſſible.

160
Diſeaſes prevalent in this country.

Though the climate of Egypt is far from being unhealthy; yet there are not a few diſeaſes which ſeem to be peculiar to it, and to have their origin either from the conſtitution of the atmoſphere, or the manner of living of the inhabitants. One of theſe till lately has been ſuppoſed to be the plague; which opinion we find ſupported by Dr Mead, who has endeavoured to aſſign a natural reaſon why it ſhould take its origin in this country. But it is now univerſally agreed, that the plague never originates in the interior parts of Egypt, but always begins at Alexandria, paſſing ſucceſſively from thence to Roſetta, Cairo, Damietta, and the reſt of the Delta. It is likewiſe obſerved, that its appearance is always preceded by the arrival of ſome veſſel from Smyrna or Conſtantinople; and that if the plague has been very violent in either of theſe cities, the danger of Egypt is the greater. On proper inquiry, it is found to be really a native of Conſtantinople; from whence it is exported by the abſurd negligence of the Turks, who refuſe to take any care to prevent the ſpreading of the infection. As they ſell even the clothes of the dead without the leaſt ceremony, and ſhips laden with this pernicious commodity are ſent to Alexandria, it is no wonder that it ſhould ſoon make its appearance there. As ſoon as it has reached Cairo, the European merchants ſhut themſelves up with their families in their *khans* or lodgings, taking care to have no further communication with the city. Their proviſions are now depoſited at the gate of the khan, and are taken up by the porter with iron tongs; who plunges them into a barrel of water provided for the purpoſe. If they have occaſion to ſpeak to any perſon, they take care to keep at ſuch a diſtance as to avoid touching or even breathing upon each other. By theſe precautions they certainly eſcape the general calamity, except by accident; and it not long ago happened that the diſeaſe was conveyed by a cat into the dwellings of the French merchants in Cairo; by which two were infected, and one died. In this manner they are impriſoned for three or four months, without any other amuſement than walking on their terraces in the evenings, cards, or converſation with one another. There is a remarkable difference betwixt the plague at Conſtantinople and in Egypt. In the former, it is moſt violent in ſummer; and in the latter in winter, ending there always in the month of June. It is alſo remarkable, that the water-carriers of Egypt, whoſe backs are conſtantly wet from the nature of their occupation, never have the plague. It appears in Egypt every fourth or fifth year, when it makes ſuch ravages as would depopulate the country, were it not for the vaſt concourſe of ſtrangers which arrive here every year from all parts of the Turkiſh empire.

A malady which ſeems in reality to be peculiar to Egypt is blindneſs. This is ſo common at Cairo, as M. Volney informs us, that out of 100 people whom he has met on the ſtreet, he might reckon 20 quite blind; 10 without the ſight of one eye; and 20 others with their eyes red, purulent, or blemiſhed. Almoſt every one, ſays he, wears a fillet, a token of an approaching or convaleſcent ophthalmy. In conſidering the cauſes of this diſorder, he reckons the ſleeping upon terraces to be a principal one. The ſouth wind, he ſays, cannot be the cauſe; otherwiſe the Bedouins would be equally ſubject to it with the Egyptians themſelves: but what is with the greateſt probability to be aſſigned as the cauſe, according to our author, is the very poor and little nutritive food which the natives are obliged to uſe. "The cheeſe, ſour-milk, honey, confection of grapes, green fruits, and raw vegetables (ſays he), which are the ordinary food of the people, produce in the ſtomach a diſorder which phyſicians have obſerved to affect the ſight; the raw onions, eſpecially, which they devour in great quantities, have a peculiar heating quality, as the monks of Syria made me remark on myſelf. Bodies thus nouriſhed, abound in corrupted humours, which are conſtantly endeavouring a diſcharge. Diverted from the ordinary channels, by habitual perſpiration, theſe humours fly to the exterior parts, and fix themſelves where they find the leaſt reſiſtance. They therefore naturally attack the head, becauſe the Egyptians, by ſhaving it once a-week, and covering it with a prodigiouſly hot head-dreſs, principally attract to it the perſpiration; and if the head receives ever ſo ſlight an impreſſion of cold on being uncovered, this perſpiration is ſuppreſſed, and falls upon the teeth, or ſtill more readily on the eyes as being the tendereſt part. It will appear the more probable that the exceſſive perſpiration of the head is a principal cauſe, when we reflect that the ancient Egyptians, who went bare-headed, are not mentioned by phyſicians as being ſo much afflicted with ophthalmies; though we are informed by hiſtorians that ſome of the Pharaohs died blind. The Arabs of the deſert alſo, who cover the head but little, eſpecially when young, are alſo very little ſubject to them." In this country blindneſs is often the conſequence of the ſmall-pox, a diſorder very frequent and very fatal

tal among the Egyptians; and no doubt the more dangerous on account of their abſurd method of treating it, of which it is needleſs to enter into any diſcuſſion in this place. They are not unacquainted with inoculation; but ſeem not to be ſenſible of its advantages, as they very ſeldom practiſe it.

To the ſame cauſe, viz. unwholeſome food, M. Volney aſcribes the general deformity of the beggars, and the miſerable appearance of the children; which he ſays are nowhere ſo wretched. "Their hollow eyes, pale and puffed faces, ſwollen bellies, meagre extremities, and yellow ſkins, make them always ſeem as if they had not long to live. Their ignorant mothers pretend that this is the effect of the *evil eye* of ſome envious perſon, who has bewitched them; and this ancient prejudice is ſtill general in Turkey: but the real cauſe is the badneſs of their food. In ſpite of the taliſmans, therefore, an incredible number of them periſh; nor is any city more fatal to the population of the neighbouring country than Grand Cairo.

The venereal diſeaſe, which, for reaſons beſt known to themſelves, the inhabitants call the *bleſſed evil*, is ſo general at Cairo, that one half of the inhabitants are infected. It is extremely difficult to cure, though the ſymptoms are comparatively very mild, inſomuch that people who are infected with it will frequently live to the age of 80; but it is fatal to children born with the infection, and exceedingly dangerous to ſuch as emigrate to a colder climate.

Beſides theſe, there are two uncommon diſeaſes met with in Egypt, viz. a cutaneous eruption which returns annually; and a ſwelling of the teſticles, which often degenerates into an enormous hydrocele. The former comes on towards the end of June or beginning of July, making its appearance in red ſpots and pimples all over the body, occaſioning a very troubleſome itching. The cauſe of this diſtemper, in M. Volney's opinion, is the corruption of the waters of the Nile, which towards the end of April become very putrid, as has already been obſerved. After this has been drunk for ſome time, the waters of the inundation, which are freſh and wholeſome, tend to introduce ſome change in the blood and humours; whence a cutaneous eruption is the natural conſequence.

The hydrocele moſt commonly attacks the Greeks and Copts; and is attributed to the quantity of oil they make uſe of, as well as to their frequent hot-bathing. Our author remarks, that "in Syria as well as in Egypt, conſtant experience has ſhown, that brandy diſtilled from common figs, or from the fruit of the ſycamore tree, as well as from dates and the fruit of the nopal, has a moſt immediate effect on the teſticles, which it renders hard and painful the third or fourth day after it has been drunk; and if the uſe of it be not diſcontinued, the diſorder degenerates into a confirmed hydrocele. Brandy diſtilled from dried raiſins has not the ſame effect: this is always mixed with aniſeeds; and is very ſtrong, being diſtilled three times. The Chriſtians of Syria and the Copts of Egypt make great uſe of it; the latter eſpecially drink whole bottles of it at their ſupper. I imagined this an exaggeration; but I have myſelf had ocular proofs of its truth, though nothing could equal my aſtoniſhment that ſuch exceſſes do not produce inſtant death, or at leaſt every ſymptom of the moſt inſenſible drunkenneſs."

In the ſpring ſeaſon malignant fevers prevail in this country; concerning which our author mentions no remarkable particular, but that eggs are a kind of poiſon, and that bleeding is very prejudicial. He recommends a vegetable diet, and the bark in very large quantity.

161 Commerce of Cairo conſiderable.

Notwithſtanding the oppreſſion which the Egyptians labour under, a very conſiderable trade is carried on from Cairo. This flouriſhing ſtate of commerce in the midſt of the moſt deſperate barbarity and deſpotiſm is owing to three cauſes. 1. That all the commodities conſumed in Egypt are collected within the walls of that city. 2. That the Mamlouks and all the people of property reſide in that place, and there ſpend their whole revenues. 3. By the ſituation of this city it is a centre of circulation; correſponding with Arabia and India, by the Red Sea; with Abyſſinia and the interior parts of Africa, by the Nile; and with Europe and the Turkiſh empire, by means of the Mediterranean. A caravan comes here annually from Abyſſinia, bringing from 1000 to 1200 ſlaves, with gum, ivory, gold-duſt, oſtrich-feathers, parrots, and monkeys.—Another, which ſets out from the extreme parts of Morocco, takes in pilgrims for Mecca from all that country as far ſouth as the mouth of the river Senegal. It conſiſts of not fewer than three or four thouſand camels, and, paſſing along the coaſts of the Mediterranean, collects likewiſe the pilgrims from Algiers, Tripoli, and Tunis, arriving at laſt at Alexandria by the way of the deſert. Proceeding thence to Cairo, it joins the Egyptian caravan; and then ſetting out both together, they take their journey to Mecca, from whence they return in one hundred days; but the Morocco pilgrims, who have ſtill 600 leagues to go, are upwards of a year in returning. The commodities they bring along with them are, India ſtuffs, ſhawls, gums, perfumes, pearls, and principally coffee. Beſides the profits of this merchandiſe, conſiderable ſums ariſe from the duties paid by pilgrims, and the ſums expended by them.

The caravans above-mentioned are not the only means by which theſe commodities are brought to Cairo. They arrive alſo at Suez, to which port the ſoutherly winds bring in the month of May ſix or eight and twenty ſail of veſſels from Jedda. Small caravans likewiſe arrive from time to time from Damaſcus with ſilk and cotton ſtuffs, oils, and dried fruits. During the proper ſeaſon there are alſo a number of veſſels in the road of Damietta, unloading hogſheads of tobacco from Latakia, vaſt quantities of which are conſumed in this country. For this commodity rice is taken in exchange; while other veſſels bring clothing, arms, furs, paſſengers, and wrought ſilk, from Conſtantinople. There are other veſſels which come from Marſeilles, Leghorn, and Venice, with cloths, cochineal, Lyons ſtuffs and laces, grocery ware, paper, iron, lead, Venetian ſequins, and German dahlers. Theſe are conveyed to Roſetta in barks called by M. Volney *djerm*, but which ſeem to be the ſame mentioned by Mr Bruce under the name of *canja*, and which are particularly deſcribed by him. He informs us, that there is a peculiarity in the form of this veſſel which makes it uſeful for navigating the river Nile; and that is, that the

162 Veſſels which navigate the Nile deſcribed.

keel

keel is not ſtraight, but a portion of a parabola, whoſe curve is almoſt inſenſible to the eye. Hence, as ſand-banks are very common in the Nile, and veſſels are apt to ſtrike them when the water becomes low, the middle of the canja will be aground while the extremities are afloat, and thus by means of oars and other aſſiſtance, it is always poſſible to get clear; but were the keel ſtraight, this would be altogether impoſſible, by reaſon of the vaſt ſails thoſe veſſels carry, which would urge them on with too much force to be recovered. The accommodation on board theſe veſſels is much better than what could be expected: but they are liable to the depredations of robbers, who either ſwim under water in the day-time, or upon goats ſkins during the night: though theſe ſeldom attack any boats where there are Europeans, whom they dread on account of their ſkill in fire arms.

From ſo many ſources we need not wonder that the commerce of Cairo ſhould be in a very flouriſhing ſtate. In 1783, according to the report of the commiſſioner-general of the cuſtoms, it amounted to no leſs than 6,250,000l.; but notwithſtanding this ſhow of wealth, the trade carried on at Cairo contributes very little to the enriching of the people. This will readily appear, when we conſider, that great part of the coffee and other merchandiſe brought from India is exported to foreign countries, the value being paid in goods from Turkey and other European countries; while the country conſumption conſiſts entirely, or moſtly, in articles of luxury already finiſhed, and the produce given in return is moſtly in raw materials.

163
Of cutting through the iſthmus of Suez.

Schemes have frequently been projected of enlarging the commerce of Egypt by cutting through the iſthmus of Suez, and thus joining the Mediterranean and Red ſeas by a canal. This is looked upon by M. Volney as impracticable. He owns, indeed, that no objection can ariſe from the diſtance, which is not more than 18 or 19 leagues; neither does any obſtacle ariſe from mountains, or the inequality of levels, the whole being a ſandy barren plain. The difficulty, which he conſiders as inſuperable, proceeds from the nature of the correſponding coaſts of the Mediterranean and Red ſeas; both of which are low and ſandy, where the waters form lakes, ſhoals, and moraſſes, ſo that ſhips cannot come within a conſiderable diſtance of either; and it would be ſcarce poſſible to cut a permanent canal amidſt theſe ſhifting ſands: not to mention, that the ſhore is deſtitute of harbours, which muſt be entirely the work of art. The country, beſides has not a drop of freſh water, which it would therefore be neceſſary to bring as far as from the Nile. The beſt method of effecting this junction, therefore, is by means of the river itſelf; and for this the ground is perfectly well calculated. This has been already done by ſeveral Egyptian princes, particularly Seſoſtris; and the canal is ſaid to have been 170 feet wide, and deep enough for large veſſels. After the Grecian conqueſt it was renewed by the Ptolemies, then by Trajan, and laſtly by the Arabs. Part of it ſtill remains, running from Cairo to the north-eaſt of the *Berket-el-Hadj*, or Lake of the Pilgrims, where it loſes itſelf. At preſent the commerce with Suez is only carried on by means of caravans, which ſet out towards the end of April or beginning of May, or in the months of July and Auguſt; waiting the arrival of the veſſels, and ſetting out on their departure. The caravans are very numerous; that with which M. Volney travelled conſiſting of 5000 or 6000 men and 3000 camels. The country is as deſert and barren as poſſible, without a ſingle tree or the ſmalleſt ſpot of verdure; ſo that every neceſſary for thoſe who accompany the caravan muſt be carried on the backs of the camels, wood and water not excepted.

The cuſtom-houſes of Egypt are in the hands of the Chriſtians of Syria. Formerly they were managed by Jews; but theſe were completely ruined by the extortions of Ali Bey in 1769. The Syrian Chriſtians came from Damaſcus ſomewhat more than 50 years ago; and having by their economy and induſtry gained poſſeſſion of the moſt important branches of commerce, they were at length enabled to farm the cuſtom-houſes, which is an office of great conſequence. There were at firſt only three or four families of them; but their number has ſince increaſed to more than 500, and they are reckoned very opulent.

164
Low ſtate of the arts and learning.

From what has already been ſaid concerning the ſtate of the Egyptians, we may naturally conclude, that the arts and all kinds of learning are at a very low ebb among them. Even the moſt ſimple of the mechanical profeſſions are ſtill in a ſtate of infancy. The work of their cabinet-makers, gun-ſmiths, and lock-ſmiths, is extremely clumſy. There are manufactures of gunpowder and ſugar; but the quality of both is very indifferent. The only thing in which they can be ſaid to arrive at any degree of perfection is the manufacture of ſilk ſtuffs; though even theſe are far leſs highly finiſhed than thoſe of Europe, and likewiſe bear a much higher price. One very extraordinary art indeed is ſtill extant among the Egyptians, and appears to have exiſted in that country from the moſt remote antiquity; and that is a power of enchanting the moſt deadly ſerpents in ſuch a manner, that they ſhall allow themſelves to be handled, nay even hurt in the ſevereſt manner, without offering to bite the perſon who injures them. Thoſe who have this art are named PSYLLI; to which article we refer for an account of what has been ſaid on the ſubject by ancient and modern travellers.

165
War in Egypt.

The long and bloody war to which the revolution of France gave riſe, induced the government of that country to leave no meaſure unattempted, by which the grandeur, independence, and commerce of Great Britain might be as much injured as poſſible, if not utterly deſtroyed. The conqueſt of Egypt was therefore projected, as a preparatory ſtep towards the ſubjugation of the Eaſt Indies, to be effected by reaching the Indian ocean through the iſthmus of Suez. This was a daring, a deſperate undertaking; and no military character of which France could boaſt, was conſidered as equal to its ſucceſsful execution but the hero of Marengo. He accordingly embarked at Toulon, as commander in chief of the army of the eaſt, which amounted to about 40,000 men, and having compelled Malta to ſurrender in the courſe of his voyage, he ſteered for the coaſt of Egypt, and arriving at Alexandria on the 1ſt of July 1798, he carried it by aſſault on the evening of the 5th.

166
Alexandria taken by the French.

It is well known that while Bonaparte continued in Italy, he ſtrictly prohibited his troops from committing acts of rapine and plunder, of which, however, they were guilty at Alexandria, and conſequently it is to be preſumed that the commander in chief could not then prevent it. If he could, he was unqueſtionably blind to his own intereſt not to do ſo, ſince nothing was more unlikely to conciliate the affections of the Egyptians. Cairo next ſurrendered to the victors on the 23d of the ſame month. The French general attacked one of the enemy's poſts at Lambabe on the 25th, when 300 of the enemy were killed; but this was only a prelude to the memorable battle of the pyramids, which was fought on the following day, and ſeemed for the preſent to decide the fate of Egypt. The Mamlouks loſt 2000 men; and 400 camels, together with their baggage and 50 pieces of cannon, fell into the hands of the conquerors. Thus far Bonaparte appeared to be the favourite of fortune, by whom he was never to be deſerted; but he ſoon found that the race is not always to the ſwift, or the battle to the ſtrong. He experienced a reverſe of an irreparable nature; and as it does not appear that he entertained the ſmalleſt apprehenſion of it, it gave a trait of ferocity to his ſubſequent conduct which he had never before exhibited.

167 Battle of the Nile.

Admiral Nelſon appeared off the mouth of the Nile on the 1ſt of Auguſt, with a naval force equal to that of the French admiral, and although the fleet of the latter was ſo ſtationed and defended as to render an attack extremely hazardous, the Britiſh hero was determined to attempt it; and in this he ſucceeded to the utmoſt of his wiſhes. He captured nine ſail of the line belonging to the enemy, L'Orient, the admiral's flag ſhip of 120 guns, having blown up during the deſperate and bloody engagement. The loſs on the part of the French muſt have been immenſe, ſince Gantheaume mentions 3100 made priſoners, whom the Britiſh commander returned: of this number there were 800 wounded. The Britiſh had about 202 killed, beſides ſixteen officers, and 678 wounded.

After Grand Cairo ſurrendered to the French, Bonaparte formed his victorious army into three diviſions, one of which was commanded by General Deſaix, whoſe deſtination was Upper Egypt, in purſuit of the flying Mamlouks; the ſecond diviſion he left for the defence of Cairo, and marched in perſon at the head of the third in purſuit of Ibrahim Bey, who had taken his route towards Syria with a rich caravan. To render abortive, if poſſible, the deſigns of Bonaparte, Britain formed an alliance with the Sublime Porte, and the chief preparations for carrying the concerted plan into effect, were made in Syria, under the care and direction of the pacha Djezzar. The frontiers of Egypt towards Syria were to be attacked by an army from Aſia Minor, the operations of which were to be favoured by making a ſtrong diverſion towards the mouths of the Nile, and by various aſſaults in Upper Egypt with the remains of Mourad Bey's army. Sir Sidney Smith left Portſmouth to ſuperintend the execution of this extenſive plan, and grant every aſſiſtance in his power by the maritime force under his command.

In the mean time care was taken to block up the harbour of Alexandria with four ſail of the line and five frigates, under the command of Commodore Hood, as he found it impracticable to burn or deſtroy the French fleet of tranſports, without the aſſiſtance of a land force ſufficient to attack Alexandria. Of the light veſſels which had been ſent him by the combined fleet of Turks and Ruſſians the commodore had made no uſe; and he alſo found the report to be without foundation, that the veſſels in the old port belonging to the French, were burnt. It was in order to deſtroy the preparations of the pacha Djezzar, and diſconcert the plans of Sir Sidney Smith, that General Bonaparte thought of leaving Egypt and marching into Syria. The reſult of this expedition, as we have already hinted, was fatal to the French intereſt, although Bonaparte perhaps never undertook an enterpriſe with more rational expectations of ultimate ſucceſs.

168 Acre defended by Sir Sidney Smith.

The town of Jaffa, (anciently Joppa), was obſtinately defended, but at laſt ſurrendered to the ſuperior tactics of European ſoldiers. From this place the French general marched with his army in three diviſions againſt St Jean d'Acre, which put an effectual period to his hitherto triumphant career. The pacha was powerfully encouraged by Sir Sidney Smith to make an obſtinate reſiſtance to the attack of Bonaparte; and to animate him ſtill more with the hopes of being able to hold out, and force the aſſailants in the iſſue to raiſe the ſiege, he ſent him a French engineer of diſtinguiſhed merit, by whoſe inſtrumentality Sir Sidney Smith had been enabled to effect his eſcape from priſon. Although the fortreſs was completely repaired by Colonel Philipeaux (the name of the engineer), yet it is more than probable that it could not have long held out againſt the ſkill and intrepidity of Bonaparte, if his heavy artillery had not been intercepted by the Britiſh on their way from Damietta and Roſetta. After a deſperate and bloody ſiege of about 61 days continuance, the French commander was obliged to abandon the hope of making Acre ſurrender. In the courſe of his retreat back again to Egypt, Bonaparte's army ravaged the whole country, burnt the harveſts, deſtroyed the defences of the different ports, the the magazines, and every reſource of which the Turks might have availed themſelves in approaching the frontiers of Egypt. He reached Grand Cairo in 26 days after raiſing the ſiege of Acre.

Sir Sidney Smith, with indefatigable zeal and activity, continued to execute the remaining parts of the plan of operations againſt Egypt, which was ſeconded by the increaſing zeal of the Turks in the proſecution of the ſame deſign. The troops deſtined to make an attack upon Alexandria were aſſembled in the different ports in the iſland of Rhodes, by Seid Muſtapha Pacha, the enterpriſe being conducted by European officers. The combined fleet of Turkey and Britain only waited the arrival of a convoy, previous to their ſailing for Egypt, which the captain pacha, who then lay at anchor in the Dardanelles, was to deſpatch to Rhodes. During the abſence of General Bonaparte, no method had been left unattempted, in order to ruin the intereſt of the French, and kindle a ſpirit of rebellion in the minds of the people. This plan ſucceeded to a certain extent, but the preſence of Bonaparte reſtored tranquillity. His army no doubt ſuffered ſeverely in its march to Syria; but with ſuch zeal and activity did he turn his attention to the re-eſtabliſhment of its organization, that it was in a condition to undertake active operations in the ſhort period of three weeks, although, according to very high authority, it had been completely buried in the burning ſands of the deſert.

While Bonaparte was in the vicinity of the pyramids, intended to purſue Mourad Bey in his retreat to Fayoum, he received intelligence from Alexandria, that a Turkiſh fleet of 100 ſail had come to anchor in the bay of Aboukir, from which 3000 troops had landed on the ſhore of the peninſula, and carried the fort of Aboukir by aſſault. He accordingly gave directions to his officers to march their forces towards the place of landing, and the firſt rendezvous of the army was appointed to be at Rhamanieh, ſituated on the left ſide of the Nile. The advanced guard under the command of General Murat, took the route to Gizeh, and General Menou's moveable column, together with the park of artillery and the ſtaff, formed a junction at Rhamanieh on the 20th of July. After the French army quitted its poſt at the village of Birket, it aſſembled at the wells between Alexandria and Aboukir; and Bonaparte fixed his head quarters at the former place.

The Turkiſh army was about 15,000 ſtrong, and receiving daily reinforcements. When Bonaparte came in ſight of it, he inſtantly formed his columns to attack it, and General d'Eſtaing carried the entrenched height of the enemy, by which their right was ſupported, at the point of the bayonet. Their two wings were cut off from retreating by General Murat, who marched up to the centre of the enemy with a body of cavalry. By this manœuvre 2000 men periſhed by water, or were killed by the fire of the republicans. As Bonaparte found that the chief ſtrength of the Turkiſh army was at the centre, he changed his poſition as the nature of the ground rendered it neceſſary. By a variety of experienced movements, in which the French loſt ſeveral brave officers, the Turks were at length thrown into the utmoſt confuſion, retreated in every direction, and threw themſelves into the ſea. The majority of them were at too great a diſtance from the veſſels, to be ſaved in this manner from a watery grave. After this battle, the fort of Aboukir was ſummoned to ſurrender, which was defended with the moſt deſperate fury, as the Turks had no idea of capitulating with arms in their hands. General Menou conducted the ſiege with great vigour and addreſs, and after bombarding it for eight days, till it exhibited nothing but a heap of ruins, the ſon of the pacha and 2000 men laid down their arms, and were made priſoners of war. In the fort the republicans found 1800 men killed, and 300 wounded. It is ſaid that Sir Sidney Smith witneſſed this melancholy reverſe of fortune on the part of the Turks, without having it in his power, as at Acre, to grant them relief, or to animate them by his courageous example.

169
Bonaparte returns to France.

The next day Bonaparte returned to Alexandria, where he learned the diſmal ſituation of French affairs on the continent of Europe, particularly in Italy and on the Rhine, and the violent commotions which were agitating the interior of France. This determined him to quit Egypt, and return to his own country, full of the idea of veſting in his own perſon the ſovereign authority, to which he has at length attained, both in name and reality. General Berthier alone was his confidential friend, to whom he communicated his future deſigns. Admiral Gantheaume was ordered to get ready two frigates with the utmoſt expedition, without informing that officer what was to be their deſtination, and brought with him Generals Laſnes, Marmont, Murat, and Andreoſſi, together with Monge and Berthollet of the inſtitute; Beſſieres and his guides received ſealed notes, which were not to be opened till a certain day, and certain hour, and at a particular point of the ſea-ſhore. They were found to contain orders for immediate embarkation; and another packet which was to be opened on the day after the ſailing of the frigates, contained the nomination of General Kleber to the chief command, and Deſaix to that of Upper Egypt.

By diſpatches from General Kleber ſubſequent to the departure of Bonaparte, it appears that Mourad Bey having dropt down the Nile to El-Ganayur, was repulſed by a diviſion of the army of Upper Egypt, under the command of General Morand. Being overtaken in his flight by this diviſion, his camp was ſurpriſed at Samahout, a vaſt number of Mamlouks were entirely cut off; 200 camels with ſpoils, 100 horſes, and a prodigious quantity of military implements fell into the hands of the republicans, and it was with the utmoſt difficulty that the bey effected his eſcape. Thus ſignally defeated, Mourad wandered through the inhoſpitable deſerts of Upper Egypt, in ſearch of an aſylum and the means of ſubſiſtence. As this man was ſuch an indefatigable enemy to the French, Deſaix reſolved to exterminate him if poſſible, and for this purpoſe two columns of infantry mounted on dromedaries were immediately organized, the one commanded by Deſaix in perſon, and the other by Adjutant-general Boyer, who came up with Mourad on the 19th of October in the deſert of Sediman, after a forced march of three days. The Mamlouks fought with determined valour and intrepidity, animated with the hopes of gaining poſſeſſion of the dromedaries. Their attack was met with ſuch vigour on the part of the republicans, that the Mamlouks and Arabs were ſoon put to flight, and purſued back to the deſerts by their intrepid conquerors.

On the 24th of September, a Turkiſh fleet of 18 veſſels came to anchor before Damietta, which was ſo rapidly increaſed by conſtant reinforcements, that it amounted to 53 about the end of the ſubſequent month. The naval commander of this fleet was Sir Sidney Smith on board the Tyger. On the 1ſt of November 4000 Turks effected a landing, who were attacked by General Verdier at the head of 1000 men, and loſt, in this apparently unequal conteſt, no fewer than 3000 men killed, 800 priſoners, including Iſmael Bey, the ſecond in command, 32 ſtand of colours, and five pieces of cannon. After a number of ſubſequent battles and inferior ſkirmiſhes which the republicans fought with various ſucceſs, they ſeemed willing to evacuate Egypt upon certain conditions, which met with the approbation of Sir Sidney Smith; but they were afterwards rejected by a ſpecies of policy for which it is difficult to account, and freſh obſtacles were thrown in the way of the propoſed evacuation. This was an event much to be deſired by the republicans, according to the opinion of ſome, while the French denied that the neceſſity of ſuch a meaſure ever exiſted. According to them, they had ſtill 20,000 effective men in that quarter of the globe, and liberally ſhared in the affections of the inhabitants, by whom they were aſſiſted.

The gallant and experienced Kleber, who ſucceeded Bonaparte

Bonaparte in the chief command of the *army of the Eaſt*, was treacherouſly aſſaſſinated by a janiſſary, while preſenting the general with a memorial for his peruſal, on which the chief command devolved on Menou, but not till ſome other generals, and Reynier in particular, had refuſed to accept of it. Suſpicions fell heavily on General Menou, who, it was ſuppoſed, had hired the aſſaſſin, as it was well known that a variance ſubſiſted between Kleber and Menou; but it is only doing juſtice to the latter to declare, that the dying aſſertions of the murderer ſufficiently evinced the contrary. He was moſt probably hired by the grand vizier himſelf; but who adviſed the vizier to the adoption of ſuch an infamous, cowardly meaſure, we muſt leave to our readers to find out. The aſſaſſin was impaled alive, his right hand burnt off, and his body left to be devoured by birds of prey. Three ſheiks who were privy to his deſigns, but did not divulge them, were beheaded.

170 Aſſaſſination of Kleber.

Lieutenant Wright was diſpatched to Cairo by Sir Sidney Smith, with propoſitions reſpecting the evacuation of Egypt to General Menou, whoſe anſwer the combined powers expected with anxiety, as the grand vizier was determined to advance againſt the enemy at the head of 30,000 men, ſhould Menou evince himſelf determined not to evacuate Egypt. He ſoon gave them to underſtand that no overtures of accommodation which they could make to him would be received. He accordingly recommenced hoſtilities, and marched againſt Syria with the principal part of his army; a meaſure which proved abortive under the auſpices of Bonaparte, by the prompt and gallant exertions of Sir Sidney Smith. The determination of Menou in ſuch a perilous ſituation, was no doubt owing in a great meaſure to the acceſſions of ſtrength which he received from the different beys who joined him, as the beſt means of ſecuring their independence, having been informed that the Sublime Porte was determined on the conqueſt of Egypt, and the deſtruction of the Mamlouks. The aid of Mourad Bey was of ſome importance to Menou, and it formed a junction of a very ſingular nature, having formerly been ſuch a determined enemy of the French. Menou ſtrongly fortified Alexandria, Damietta, and Roſetta, and not only finiſhed the lines which Colonel Bromley had begun at Aboukir, but made to theſe ſeveral important additions, putting every place into ſuch a ſtate of defence as ſeemed to bid defiance to any attack from the Turks.

In the mean time Britain was not idle, but active in the organization of an army deſtined to invade Egypt, and compel the French troops to evacuate that country, which was too contiguous to her ineſtimable poſſeſſions in the Eaſt Indies; and the command of it was given to that gallant and highly reſpectable officer, the late general Sir Ralph Abercromby, who appeared off Aboukir in the beginning of March, 1801. The weather proving unfavourable for ſome days, Sir Ralph did not begin to land his troops till the 8th, at an early hour in the morning. The French having marched from Alexandria, took their ſtation on the heights of Aboukir, to prevent the landing of the Britiſh forces. An action ſoon commenced between the hoſtile armies, which laſted for two hours, but the republicans were obliged to retreat, having only 4000 men to oppoſe to three times that number. The loſs of the French on this occaſion was eſtimated at 3000, and that of the Britiſh about 1500 men, in killed, wounded, and priſoners.

171 The Britiſh under Abercromby victorious at Aboukir.

After this, few actions of importance occurred till the memorable 21ſt of March, on which day a battle was fought about four miles from Alexandria. A falſe attack on the left of the Britiſh army was the commencement of hoſtilities, but the French were ſtill more anxious to turn the right of their opponents, which they attempted in vain. With the ſame ſucceſs they made an attack upon the central diviſion. About 200 priſoners fell into the hands of the Britiſh, but as their cavalry was much inferior to that of the enemy, whoſe retreat was alſo covered by cannon on the oppoſite hills, they could not purſue their advantages. The loſs of the Britiſh at this time was very conſiderable, but the moſt irreparable part of it was the loſs of the commander in chief, who was mortally wounded on the 21ſt, and died on the 28th of the ſame month. He was ſucceeded by General Hutchinſon, the ſecond in command, to whom was committed the completion of the plans which his worthy predeceſſor had concerted. He attacked the French on the 19th of May, near Rhamanieh, and forced them to retire towards Cairo. He had 4000 Britiſh troops under his command, and an equal number of Turks under the captain pacha. He then directed his route towards Cairo, from which the army of the grand vizier was diſtant only four leagues, in a north-eaſt direction. A reinforcement of 3000 Britiſh troops reached Aboukir about the 6th of May.

By the advice of Colonel Murray and ſome other Britiſh officers then in the camp of the grand vizier, his highneſs obtained a victory over 4600 French, with 9000 choſen troops, not encumbered with the women and uſeleſs attendants ſo commonly met with in the camps of eaſtern generals. The whole of Damietta ſoon fell into the hands of the allies, and the ſucceſſor of Mourad Bey declared in favour of the Britiſh, joining Sir J. Hutchinſon with 1500 cavalry, that kind of force of which the Britiſh commander ſtood in greateſt need. In a ſhort time after, the French evacuated Cairo, which was taken poſſeſſion of by the combined Turkiſh and Britiſh army. The republicans were not made priſoners, but were, by ſtipulation, to be conveyed to the neareſt ports belonging to France, at the expence of Great Britain. Alexandria ſtill held out, which Menou was determined to defend to the laſt, notwithſtanding the idea of receiving reinforcements appeared altogether groundleſs. He was at length, however, obliged to ſurrender, and thus the whole of Egypt was in poſſeſſion of the allies. As the joyful news of peace between Great Britain and France had ſpread over the country prior to this intelligence, it did not excite half the intereſt in the mind of Britons which it would otherwiſe have done.

For a deſcription of thoſe ſtupendous and almoſt indeſtructible monuments of human grandeur, the pyramids, ſo often taken notice of and deſcribed by travellers, ſee the article PYRAMIDS.

EGYPTIANS, or GYPSIES. See GYPSIES.

EHRETIA, a genus of plants belonging to the pentandria claſs. See BOTANY *Index*.

EHRHARTA, a genus of plants belonging to the hexandria claſs. See BOTANY *Index*.

EHUD, the ſon of Gera, a Benjamite, a man left-handed,

handed, who delivered Iſrael from the oppreſſion of Eglon king of Moad, under whom they ſerved for 18 years. See EGLON. It being cuſtomary for the Iſraelites to ſend a preſent or tribute to the king of Moab; in the year of the world 2579, being the laſt year of their ſervitude, Ehud was appointed to carry it, who having a deſign either to free his country from this oppreſſion, or periſh in the attempt, had for this purpoſe provided himſelf with a dagger which had two edges, and which he had concealed on his right ſide, (Judges iii. 15. &c.). After he had delivered the preſent, pretending he had ſomething of great importance to communicate to the king, he obtained a private audience of him; when taking his opportunity, he ſtabbed him with the poniard to the heart, and ſo ſhutting the door after him, had time to make his eſcape; for as the king was a very corpulent man, his attendants ſuppoſed that he was either repoſing or eaſing himſelf, and therefore forbore to enter his apartment until Ehud was quite gone. As ſoon as he came to Mount Ephraim, he gathered together the Iſraelites that lay neareſt him, acquainted them with what he had done; and then ſecuring the fords of Jordan that none of them might eſcape, he fell upon the Moabites, and ſubdued them.

EIA, or EY, in our old writers, is uſed for an iſland. Hence the names of places ending in *ey*, denote them to be iſlands. Thus, Ramſey, the iſle of rams; Shepey, the iſle of ſheep, &c.

EIA is alſo ſometimes uſed for water; and hence the names of places near waters or lakes terminate in *ey*.

EJACULATOR, in *Anatomy*, a name applied to two muſcles of the penis, from their office in the ejection of the ſeed. See ANATOMY, *Table of the Muſcles*.

EICETÆ, called alſo HEICETÆ and HICETÆ, heretics of the ſeventh century, who made profeſſion of the monaſtic life.—From that paſſage in Exodus where Moſes and the children of Iſrael are ſaid to have ſung a ſong in praiſe of the Lord, after they had paſſed the Red ſea, wherein their enemies had periſhed; the eicetæ concluded, that they muſt ſing and dance to praiſe God aright: and as Mary the propheteſs, ſiſter of Moſes and Aaron, took a drum in her hand, on the ſame occaſion, and all the women did the like, to teſtify their joy, by playing, beating, and dancing; the eicetæ, the better to imitate their conduct herein, endeavoured to draw women to them to make profeſſion of the monaſtic life, and aſſiſt in their mirth.

EICK. See BRUGES.

EIDER-DUCK. See ANAS, ORNITHOLGGY *Index*.

Eider-Down, the down of the eider-duck. The eider-duck plucks off the down from its breaſt for the purpoſe of making its neſt, which, after being robbed by thoſe who collect the down, is renewed by the bird till its breaſt is quite bare.

EJECTA, a term uſed by lawyer for a woman deflowered or caſt from the virtuous.

EJECTION, in the animal economy, the evacuation, or diſcharging any thing through ſome of the emunctories, as by ſtool, vomit, &c.

EJECTION, in *Scots Law*, is the turning out the poſſeſſor of any heritable ſubject by force; and is either *legal* or *illegal*. Legal ejection is where a perſon having no title to poſſeſs, is turned out by the authority of law. Illegal ejection is one perſon's violently turning another out of poſſeſſion without lawful authority.

EJECTMENT, in *Engliſh Law*, a writ or action which lies for the leſſee for years, on his being ejected or put out of his land, before the expiration of his term, either by the leſſor or a ſtranger. It may alſo be brought by the leſſor againſt the leſſee, for rent in arrears, or holding over his term, &c. Ejectment of late years is become an action in the place of many real actions, as writs of right, formedons, &c. which are very difficult, as well as tedious and expenſive; and this is now the common action for trial of titles, and recovering of lands, &c. illegally held from the right owner; yet where entry is taken away by diſcents, fines, recoveries, diſſeiſins, &c. an ejectment ſhall not be brought; whereby we find that all titles cannot be tried by this action.

The method of proceeding in the action of ejectment is to draw up a declaration, and feign therein a leaſe for three, five, or ſeven years, to him that would try the title; and alſo feign a caſual ejector or defendant; and then deliver the declaration to the ejector, who ſerves a copy of it on the tenant in poſſeſſion, and gives notice at the bottom for him to appear and defend his title; or that he the feigned defendant will ſuffer judgment by default, whereby the true tenant will be turned out of poſſeſſion: to this declaration the tenant is to appear at the beginning of next term by his attorney, and conſent to a rule to be made defendant, inſtead of the caſual ejector, and take upon him the defence, in which he muſt confeſs leaſe, judgment, entry, and auſter, and at the trial ſtand upon the title only: but in caſe the tenant in poſſeſſion does not appear, and enter into the ſaid rule in time, after the declaration ſerved, then, on affidavit being made of the ſervice of the declaration, with the notice to appear as aforeſaid, the court will order judgment to be entered againſt the caſual ejector by default; and thereupon the tenant in poſſeſſion, by writ *habere facias poſſeſſionem*, is turned out of his poſſeſſion. On the trial in ejectment, the plaintiff's title is to be ſet forth from the perſon laſt ſeiſed in fee of the lands in queſtion, under whom the leſſor claims down to the plaintiff, proving the deeds, &c. and the plaintiff ſhall recover only according to the right which he has at the time of bringing his action. And here, another who hath title to the land, upon a motion made for that purpoſe, may be defendant in the action with the tenant in poſſeſſion, to defend his title; for the poſſeſſion of the lands is primarily in queſtion, and to be recovered, which concerns the tenant, and the title thereto is tried collaterally, which may concern ſome other.

EKRON, a city and government of the Philiſtines. It fell by lot to the tribe of Judah, in the firſt diviſion made by Joſhua (xv. 45.), but afterwards it was given to the tribe of Dan (*id.* xix. 43.). It was ſituated very near the Mediterranean, between Aſhdod and Jamnia. Ekron was a powerful city, and it does not appear by hiſtory that the Jews were ever ſole peaceable poſſeſſors of it: the Ekronites were the firſt who ſaid that it was neceſſary to ſend back the ark of the God of Iſrael, in order to be delivered from thoſe calamities which the preſence of it brought upon their country, (1 Sam. v. 10.). The idol Baalzebub was principally adored at Ekron (2 Kings, i. 2. &c.)

ELÆAGNUS, Oleaster, or *Wild Olive:* A genus of plants, belonging to the tetrandria claſs. See Botany *Index*.

ELÆOCARPUS, a genus of plants belonging to the polyandria claſs. See Botany *Index*.

ELÆOTHESIUM, in antiquity, the anointing room, or place where thoſe who were to wreſtle or had bathed anointed themſelves. See Gymnasium.

ELAIS, a genus of plants belonging to the natural order of *Palmæ*. See Botany *Index*.

ELAM, in *Ancient Geography*, a country frequently mentioned in Scripture, and lying to the ſouth-eaſt of Shinar. In the time of Daniel (viii. 2.), Suſiana ſeems to have been part of it; and before the captivity, it does not appear that the Jews called Perſia by any other name. Elymæ and Elymais are often mentioned by the ancients. Ptolemy, though he makes Elymais a province of Media, yet he places the Elymæ in Suſiana, near the ſea-coaſt. Stephanus takes it to be a part of Aſſyria; but Pliny and Joſephus more properly of Perſia, whoſe inhabitants this latter tells us ſprang from the Elamites. The beſt commentators agree, that the Elamites, who were the anceſtors of the Perſians, were deſcended from Elam the ſon of Shem. It is likewiſe allowed, that the moſt ancient among the inſpired writers conſtantly intend Perſia, when they ſpeak of Elam and the kingdom of Elam. Thus, not to detain the reader with unneceſſary quotations, when the prophet Jeremiah (xlix. 39.), after denouncing many judgments againſt this country, adds theſe words, "But it ſhall come to paſs in the latter days, that I will bring again the captivity of Elam, ſaith the Lord," he is always underſtood to mean the reſtoration of the kingdom of the Perſians by Cyrus, who ſubdued the Babylonians, as they before had ſubdued the Perſians.

ELAPHEBOLIA, in Grecian antiquity, a feſtival in honour of Diana the huntreſs. In the celebration a cake was made in the form of a deer (ελαφος), and offered to the goddeſs. It owed its inſtitution to the following circumſtance: When the Phocians had been ſeverely beaten by the Theſſalians, they reſolved, by the perſuaſion of one Deiphantus, to raiſe a pile of combuſtible materials, and burn their wives, children, and effects, rather than ſubmit to the enemy. This reſolution was unanimouſly approved by the women, who decreed Deiphantus a crown for his magnanimity. When every thing was prepared, before they fired the pile, they engaged their enemies, and fought with ſuch deſperate fury, that they totally routed them, and obtained a complete victory. In commemoration of this unexpected ſucceſs, this feſtival was inſtituted to Diana, and obſerved with the greateſt ſolemnity.

ELAPHEBOLIUM, in Grecian antiquity, the ninth month of the Athenian year, anſwering to the latter part of February and beginning of March. It conſiſted of 30 days; and took its name from the feſtival elaphebolia, kept in this month, in honour of Diana the huntreſs, as mentioned in the preceding article.

ELASMIS, in *Natural Hiſtory*, a genus of talcs, compoſed of ſmall plates in form of ſpangles; and either ſingle, and not farther fiſſile; or, if complex, only fiſſile to a certain degree, and that in ſomewhat thick laminæ.—Of theſe talcs there are ſeveral varieties, ſome with large and others with ſmall ſpangles, which differ alſo in colour and other peculiarities.

ELASTIC, in *Natural Philoſophy*, an appellation given to all bodies endowed with the property of elaſticity. See Elasticity.

Elastic Fluids. See Air, Electricity, Gas, and *Elastic Vapours* below.

Elastic Reſin. See Caoutchouc.

Elastic Vapours are ſuch as may, by any external mechanical force, be compreſſed into a ſmaller ſpace than what they originally occupied; reſtoring themſelves, when the preſſure is taken off, to their former ſtate with a force exactly proportioned to that with which they were at firſt compreſſed. Of this kind are all the aerial fluids without exception, and all kinds of fumes raiſed by means of heat whether from ſolid or fluid bodies.

Of theſe, ſome retain their elaſticity only when a conſiderable degree of heat is applied to them or the ſubſtance which produces them; while others remain elaſtic in every degree of cold, either natural or artificial, that has yet been obſerved. Of the former kind are the vapours of water, ſpirit of wine, mercury, ſal ammoniac, and all kinds of ſublimable ſalts; of the latter, thoſe of muriatic acid gas, hydrogen gas, nitrous gas, common air, &c.

The elaſtic force with which any one of theſe fluids is endowed has not yet been calculated, as being ultimately greater than any obſtacle we can put in its way. Thus, if we compreſs the atmoſpherical air, we ſhall find that for ſome little time it will eaſily yield to the force we apply; but every ſucceeding moment the reſiſtance will become ſtronger, and a greater and greater force muſt be applied in order to compreſs it farther. As the compreſſion goes on, the veſſel containing the air becomes hot; but no power whatever has yet been able to deſtroy the elaſticity of the contained fluid in any degree; for upon removing the preſſure, it is always found to occupy the very ſame ſpace that it did before. The caſe is the ſame with aqueous ſteam, to which a ſufficient heat is applied to keep it from condenſing into water. This will yield to a certain degree: but every moment the reſiſtance becomes greater, until at laſt it will overcome any obſtacles whatever. An example of the power of this kind of ſteam we have every day in the ſteam engine; and the vapours of other matters, both ſolid and fluid, have frequently manifeſted themſelves to be endowed with an equal force. Thus the force of the vapours of ſpirit of wine has occaſioned terrible accidents when the worm has been ſtopped, and the head of the ſtill abſurdly tied down to prevent an exploſion; the vapours of mercury have burſt an iron box; and thoſe of ſal ammoniac, volatile ſalts, nitrous acid, marine acid, phoſphorus, &c. have all been known to burſt the chemical veſſels which confined them with great force, in ſuch a manner as to endanger thoſe who ſtood near them. In ſhort, from innumerable obſervations, it may be laid down as an undoubted fact, that there is no ſubſtance whatever capable of being reduced into a ſtate of vapour, but what in that ſtate is endowed with an elaſtic force ultimately ſuperior to any obſtacle we can throw in its way.

It hath been a kind of deſideratum among philoſophers to give a ſatisfactory reaſon for this aſtoniſhing power of elaſticity in vapour, ſeemingly ſo little capable of accompliſhing any great purpoſe when in an unconfined ſtate. As air is that fluid in which, from the many experiments made upon it by the air-pump and otherwiſe, the elaſtic property has moſt frequently been obſerved, the reſearches of philoſophers were at firſt principally directed towards it. The cauſes they aſſigned, however, were very inadequate; being founded upon an hypotheſis concerning the form of the particles of the atmoſphere itſelf, which they ſuppoſed to be either rolled up like the ſprings of watches, or that they conſiſted of a kind of elaſtic flakes. This was followed by another hypotheſis concerning their ſubſtance, which was imagined to be perfectly elaſtic, and ſo ſtrong that they could not be broken by any mechanical power whatever; and thus they thought the phenomenon of the elaſticity of the air might be explained. But an inſuperable difficulty ſtill attended their ſcheme, notwithſtanding both theſe ſuppoſitions; for it was obſerved, that the elaſtic power of the air was augmented not only in proportion to the quantity of preſſure it was made to endure, but in proportion to the degree of heat applied to it at the time. Sir Iſaac Newton was aware of this difficulty; and juſtly concluded, that the phenomena of the air's elaſticity could not be ſolved on any other ſuppoſition but that of a repulſive power diffuſed all around each of its particles, which became ſtronger as they approached, and weaker as they removed from each other. Hence the common phenomena of the air-pump and condenſing-engine received a ſatisfactory explanation; but ſtill it remained to account for the power ſhown in the preſent caſe by heat, as it could not be denied that this element had a very great ſhare in augmenting the elaſticity of the atmoſphere, and ſeemed to be the only cauſe of elaſticity in other vapours. It does not appear that Sir Iſaac entered into this queſtion, but contented himſelf with attributing to heat the property of increaſing repulſion, and aſcribing this to another unexplored property called *rarefaction*. Thus matters ſtood till the great diſcovery made by Dr Black, that ſome bodies have the power of abſorbing in an unknown manner the element in queſtion, and parting with it afterwards, ſo that it flows out of the body which had abſorbed it with the very ſame properties that it had before abſorption. Hence many phenomena of heat, vapour, and evaporation, were explained in a manner much more ſatisfactory than had ever been attempted or even expected before. One of theſe was that remarkable property of metals becoming hot by hammering; during which operation, in the Doctor's opinion, the element of heat is ſqueezed out from between the particles of the metal, as water is from the pores of a ſponge by preſſing it between the fingers. Of the ſame nature is the phenomenon above-mentioned, that air when violently compreſſed becomes hot, by reaſon of the quantity of more ſubtle element ſqueezed out from among the particles. In this manner it appears that heat and the repulſive power of Sir Iſaac Newton are the very ſame; that by diminiſhing the heat of any quantity of air, its elaſticity is effectually diminiſhed, and it will of itſelf ſhrink into a ſmaller ſpace as effectually as by mechanical preſſure. In one caſe we have what may be called ocular demonſtration of the truth of this doctrine, viz. that by throwing the focus of a ſtrong burning lens upon a ſmall quantity of charcoal *in vacuo*, the whole will be converted into inflammable air, having even a greater power of elaſticity than common air in an equal degree of heat. Here there is nothing elſe but heat or light to produce the elaſtic power, or cauſe the particles of charcoal which before *attracted* now to repel each other. In another caſe we have evidence equally ſtrong, that the element of heat by itſelf, without the preſence of that of light, is capable of producing the ſame effect. Thus when a phial of ether is put into the receiver of an air pump, and ſurrounded by a ſmall veſſel of water, the ether boils violently, and is diſſipated in vapour, while the water freezes, and is cooled to a great degree. The diſſipation of this vapour ſhows that it has an elaſtic force; and the abſorption of the heat from the water ſhows, that this element not only *produces* the elaſticity, but actually enters into the ſubſtance of the vapour itſelf; ſo that we have not the leaſt reaſon to conclude that there is any other repulſive power by which the particles are kept at a diſtance from one another than the ſubſtance of the heat itſelf. In what manner it acts, we cannot pretend exactly to explain, without making hypotheſes concerning the form of the minute particles of matter, which muſt always be very uncertain. All known phenomena, however, concur in rendering the theory juſt now laid down extremely probable. The elaſticity of the ſteam of water is exactly proportioned to the degree of heat which flows into it from without; and if this be kept up to a ſufficient degree, there is no mechanical preſſure which can reduce it into the ſtate of water. This, however, may very eaſily be done by abſtracting a certain portion of the latent heat it contains; when the elaſtic vapour will become a denſe and heavy fluid. The ſame thing may be done in various ways with the permanently elaſtic fluids. Thus the pureſt dephlogiſticated air, when made to part with its latent heat by burning with iron, is converted into a gravitating ſubſtance of an unknown nature, which adheres ſtrongly to the metal. If the decompoſition is performed by means of inflammable air, both together unite into an heavy, aqueous, or acid fluid: if by mixture with nitrous air, ſtill the heat is diſcernible, though leſs violent than in the two former caſes. The decompoſition indeed is ſlower, but equally complete, and the dephlogiſticated air becomes part of the nitrous acid, from which it may be again expelled by proper means; but of theſe means heat muſt always be one; for thus only the elaſticity can be reſtored, and the air be recovered in its proper ſtate. The ſame thing takes place in fixed air, and all other permanently elaſtic fluids capable of being abſorbed by others. The concluſion therefore which we can only draw from what data we have concerning the compoſition of elaſtic vapours is, that all of them are formed of a terreſtrial ſubſtance, united with the element of heat in ſuch a manner that part of the latter may be ſqueezed out from among the terreſtrial particles; but in ſuch a manner, that as ſoon as the preſſure is taken off, the ſurrounding fluid ruſhes in, and expands them to their original bulk: and this expanſion or tendency to it will be increaſed in proportion to the degree of heat, juſt as the expanſion of a ſponge would be exceedingly augmented, if we could contrive to convey a ſtream of water into

into the heart of it, and make the liquid flow out with violence through every pore in the circumference. In this caſe, it is evident that the water would act as a *power of repulſion* among the particles of the ſponge, as well as the fire does among the particles of the water, charcoal, or whatever other ſubſtance is employed. Thus far we may reaſon from analogy; but in all probability the internal and eſſential texture of theſe vapours will for ever remain unknown. Their obvious properties, as well as ſome of their more latent operations in many caſes, are treated of under CHEMISTRY.

It has been imagined by ſome, that the artificial elaſtic fluids have not the ſame mechanical property with common air, viz. that of occupying a ſpace inverſely proportional to the weights with which they are preſſed: but this is found to be a miſtake. All of them likewiſe have been found to be non-conductors of electricity, though probably not all in the ſame degree. Even aqueous vapour, when intimately mingled with any permanently elaſtic fluid, refuſes to conduct this fluid, as is evident from the highly electrical ſtate of the atmoſphere in very dry weather, when we are certain that aqueous vapour muſt abound very much, and be intimately mixed with it. The colour of the electric ſpark, though it may be made viſible in all kinds of permanently elaſtic vapours, is very different in different fluids. Thus in inflammable and alkaline air it is red or purple, but in fixed air it appears white.

ELASTICITY, or ELASTIC *Force*, that property of bodies wherewith they reſtore themſelves to their former figure, after any external preſſure.

The cauſe or principle of this important property elaſticity, or ſpringineſs, is variouſly aſſigned. The Carteſians account for it from the materia ſubtilis making an effort to paſs through pores that are too narrow for it. Thus, ſay they, in bending, or compreſſing, a hard elaſtic body, e. gr. a bow, its parts recede from each other on the convex ſide, and approach on the concave: conſequently the pores are contracted or ſtraitened on the concave ſide; and if they were before round, are now, for inſtance, oval: ſo that the materia ſubtilis, or matter of the ſecond element, endeavouring to paſs out of thoſe pores thus ſtraitened, muſt make an effort, at the ſame time, to reſtore the body to the ſtate it was in when the pores were more patent and round, i. e. before the bow was bent: and in this conſiſts its elaſticity.

Other later and more wary philoſophers account for elaſticity much after the ſame manner as the Carteſians; with this only difference, that in lieu of the ſubtile matter of the Carteſians, theſe ſubſtitute ETHER, or a fine ethereal medium that pervades all bodies.

Others, ſetting aſide the precarious notion of a materia ſubtilis, account for elaſticity from the great law of nature ATTRACTION, or the cauſe of the COHESION of the parts of ſolid and firm bodies. Thus, ſay they, when a hard body is ſtruck or bent, ſo that the component parts are moved a little from each other, but not quite disjointed or broke off, or ſeparated ſo far as to be out of the power of that attractive force whereby they cohere; they muſt certainly, on the ceſſation of the external violence, ſpring back to their former natural ſtate.

Others reſolve elaſticity into the preſſure of the atmoſphere; for a violent tenſion or compreſſion, though not ſo great as to ſeparate the conſtituent particles of bodies far enough to let in any foreign matter, muſt yet occaſion many little vacuola between the ſeparated ſurfaces; ſo that upon the removal of the force they will cloſe again by the preſſure of the aerial fluid upon the external parts. See ATMOSPHERE.

Laſtly, others attribute the elaſticity of all hard bodies to the power of reſilition in the air included within them: and ſo make the elaſtic force of the air the principle of elaſticity in all other bodies.

The ELASTICITY *of Fluids* is accounted for from their particles being all endowed with a centrifugal force; when Sir Iſaac Newton, prop. 23. lib. 2. demonſtrates, that particles, which naturally avoid or fly off from one another by ſuch forces as are reciprocally proportioned to the diſtances of their centre, will compoſe an elaſtic fluid, whoſe denſity ſhall be proportional to its compreſſion; and *vice verſa*, if any fluid be compoſed of particles that fly off and avoid one another, and hath its denſity proportional to its compreſſion, then the centrifugal forces of thoſe particles will be reciprocally as the diſtances of their centres.

ELASTICITY *of the Air*, is the force wherewith that element dilates itſelf, upon removing the force whereby it was before compreſſed. See AIR and ATMOSPHERE.

The elaſticity or ſpring of the air was firſt diſcovered by Galileo. Its exiſtence is proved by this experiment of that philoſopher: An extraordinary quantity of air being intruded by means of a ſyringe into a glaſs or metal ball, till ſuch time as the ball, with this acceſſion of air, weighs conſiderably more in the balance than it did before; upon opening the mouth thereof, the air ruſhes out, till the ball ſink to its former weight. From hence we argue, that there is juſt as much air gone out, as compreſſed air had been crowded in. Air, therefore, returns to its former degree of expanſion, upon removing the force that compreſſed or reſiſted its expanſion; conſequently it is endowed with an elaſtic force. It muſt be added, that as the air is found to ruſh out in every ſituation or direction of the orifice, the elaſtic force acts every way, or in every direction.

The elaſticity of the air makes a conſiderable article in PNEUMATICS.

The cauſe of the elaſticity of the atmoſphere hath been commonly aſcribed to a repulſion between its particles; but this can give us only a very ſlight idea of the nature of its elaſticity. The term *repulſion*, like that of *attraction*, requires to be defined; and in all probability will be found in moſt caſes to be the effect of the action of ſome other fluid. Thus, we find, that the elaſticity of the atmoſphere is very conſiderably affected by heat. Suppoſing a quantity of air heated to ſuch a degree as is ſufficient to raiſe Fahrenheit's thermometer to 212, it will then occupy a conſiderable ſpace. If it is cooled to ſuch a degree as to ſink the thermometer to 0, it will ſhrink up into leſs than half the former bulk. The quantity of repulſive power therefore acquired by the air, while paſſing from one of theſe ſtates to the other, is evidently owing to the heat added to or taken away from it. Nor have we any reaſon to ſuppoſe, that the quantity of elaſticity or repulſive power it ſtill poſſeſſes is owing to any other thing than the fire contained in it. The ſuppoſing repulſion to be a primary cauſe, independent of all others, hath given riſe to many erroneous theories, and been one very great mean of embarraſſing philoſophers in their accounting for the phenomena of ELECTRICITY.

ELATE, a genus of plants belonging to the natural order of *Palmæ*. See BOTANY *Index*.

ELATER, a genus of inſects belonging to the or-order of *Coleoptera*. See ENTOMOLOGY *Index*.

ELATERIUM, a genus of plants belonging to the monœcia claſs. See BOTANY *Index*.

ELATERIUM, Ελατηριον, in *Pharmacy*, a violently purgative medicine, prepared from the wild cucumber.

ELATH, or ELOTH, a port of Idumæa, ſituated upon the Red ſea, which David in his conqueſt of Edom took (2 Sam. viii. 14.), and there eſtabliſhed a trade to all parts of the world. His ſon, we ſee, built ſhips in Elath, and ſent them from thence to Ophir for gold, (2 Chr. viii. 17, 18.). It continued in the poſſeſſion of the Iſraelites about 150 years, till in the time of Joram, the Edomites recovered it (2 Kings viii. 20.); but it was again taken from them by Azariah, and by him left to his ſon, (2 Kings xiv. 22.). His grandſon Ahaz, however, loſt it again to the king of Syria (*ib*. xvi. 6.); and the Syrians had it in their hands a long while, till after many changes under the Ptolemies, it came at length into the poſſeſſion of the Romans.

ELATINE, a genus of plants belonging to the octandria claſs. See BOTANY *Index*.

ELATOSTEMA, a genus of plants belonging to the monœcia claſs. See BOTANY *Index*.

ELBE, a large river in Germany, which, riſing on the confines of Sileſia, runs through Bohemia, Saxony, and Brandenburg; and afterwards dividing the duchy of Luxemburg from that of Mecklenburg, as alſo the duchy of Bremen from Holſtein, it falls into the German ocean, about 70 miles below Hamburg. It is navigable for great ſhips higher than any river in Europe.

ELBING, a city of Poliſh Pruſſia, in the palatinate of Marienburg, ſituated in E. Long. 20. 0. N. Lat. 54. 15, on a bay of the Baltic ſea, called the *Friſchaff*, near the mouth of the Viſtula. The town is large, populous, and very well built. It is divided into two parts, called the old and new town, which are both of them very well fortified. The old town has a handſome tower, with a good college. The ſtadthouſe and the academy are good buildings, with pleaſant gardens, which are worth ſeeing. The place has a conſiderable trade, eſpecially in ſturgeon, mead, cheeſe, butter, and corn. It is ſeated in a champaign level like Holland, very fruitful and populous. The inhabitants are partly Lutherans and partly Roman Catholics. The boors in the neighbourhood have as good houſes and apparel almoſt as the nobility of Courland.

ELBOW, the outer angle made by the flexure or bend of the arm. That eminence whereon the arm reſts, called by us *elbow*, is by the Latins called *cubitus*, and the Greeks αγκων, and by others ολεκρανον.

ELBOW is alſo uſed by architects, maſons, &c. for an obtuſe angle of a wall, building, or road, which diverts it from its right line.

ELCESAITES, in church hiſtory, ancient heretict, who made their appearance in the reign of the emperor Trajan, and took their name from their leader Elceſai. The Elceſaites kept a mean between the Jews, Chriſtians, and Pagans; they worſhipped but one God, obſerved the Jewiſh ſabbath, circumciſion, and the other ceremonies of the law. They rejected the Pentateuch, and the prophets: nor had they any more reſpect for the writings of the apoſtles, particularly thoſe of St Paul.

ELDERS, or SENIORS, in Jewiſh hiſtory, were perſons the moſt conſiderable for age, experience, and wiſdom. Of this ſort were the 70 men whom Moſes aſſociated to himſelf in the government of his people: ſuch, likewiſe, afterwards were thoſe who held the firſt rank in the ſynagogue, as preſidents.

In the firſt aſſemblies of the primitive Chriſtians, thoſe who held the firſt place were called *elders*. The word *preſbyter*, often uſed in the New Teſtament, is of the ſame ſignification: hence the firſt councils of Chriſtians were called *preſbyteria*, or *councils of elders*.

ELDERS is alſo a denomination ſtill retained in the Preſbyterian diſcipline. The elders are officers, who, in conjunction with the paſtors, or miniſters, and deacons, compoſe the conſiſtories or kirk-ſeſſions, meeting to conſider, inſpect, and regulate, matters of religion and diſcipline. They are choſen from among the people, and are received publicly with ſome degree of ceremony. In Scotland, there is an indefinite number of elders in each pariſh; generally about 12. See *KIRK-Seſſions* and PRESBYTERY.

ELDER. See SAMBUCUS, BOTANY *Index*.

ELEA, or ELIS, in *Ancient Geography*, a diſtrict of Peloponneſus, ſituated between Achaia and Meſſenia, reaching from Arcadia quite to the weſt or Ionian ſea: ſo called from ELIS, a cognominal town. See ELIS.

ELEATIC PHILOSOPHY, among the ancients, a name given to that of the STOICS, becauſe taught at Ελεα, in Latin *Velia*, a town of the Lucani.

The founder of this philoſophy, or of the Eleatic ſect, is ſuppoſed to have been Xenophanes, who lived about the 56th Olympiad, or between 500 or 600 years before Chriſt. This ſect was divided into two parties, which may be denominated *metaphyſical* and *phyſical*, the one rejecting, and the other approving, the appeal to fact and experiment. Of the former kind were Xenophanes, Parmenides, Meliſſus, and Zeno of Elea. They are ſuppoſed to have maintained principles not very unlike thoſe of Spinoza; they held the eternity and immutability of the world; that whatever exiſted was only one being; that there was neither any generation nor corruption; that this one being was immoveable and immutable, and was the true God; and whatever changes ſeemed to happen in the univerſe, they conſidered as mere appearances and illuſions of ſenſe. However, ſome learned men have ſuppoſed, that Xenophanes and his followers, ſpeaking metaphyſically, underſtood by the univerſe, or the one being, not the material world, but the originating principle of of all things, or the true God, whom they expreſsly affirm to be incorporeal. Thus Simplicius repreſents them as merely metaphyſical writers, who diſtinguiſhed between things natural and ſupernatural; and who made the former to be compounded of different principles. Accordingly, Xenophanes maintained, that the earth conſiſted of air and fire; that all things were produced out of the earth, and the ſun and ſtars out of clouds, and that there were four elements. Parmenides alſo diſtinguiſhed between the doctrine concerning metaphyſical objects, called *truth*, and that concerning phyſical or corporeal things, called *opinion;* with reſpect to the former there was one immoveable principle, but in the latter two that were moveable, viz. fire and earth, or heat and cold; in which particulars Zeno agreed with him. The other branch of the Eleatic ſect were the atomic philoſophers, who formed their ſyſtem from an attention to the phenomena of nature; of theſe the moſt conſiderable were Leucippus, Democritus, and Protagoras.

ELECAMPANE. See INULA, BOTANY *Index*.

ELECT, (from *eligo*, "I chooſe") CHOSEN, in the Scriptures, is applied to the primitive Chriſtians, in which ſenſe, the elect are thoſe choſen and admitted to the favour and bleſſing of Chriſtianity.

ELECT, in ſome ſyſtems of theology, is a term appropriated to the ſaints, or the predeſtinated: in which ſenſe the elect are thoſe perſons who are ſaid to be predeſtinated to glory as the end, and to ſanctification as the means.

ELECT is likewiſe applied to archbiſhops, biſhops, and other officers, who are choſen, but not yet conſecrated, or actually inveſted with their office or juriſdiction.

The emperor is ſaid to be elect before he is inaugurated and crowned; a lord-mayor is elect, before his predeceſſor's mayorality is expired, or the ſword is put is his hands.

ELECTION, the choice that is made of any thing or perſon, whereby it is preferred to ſome other. There ſeems this difference, however, between choice and election, that election has uſually a regard to a company or community, which makes the choice; whereas choice is ſeldom uſed but when a ſingle perſon makes it.

ELECTION, in Britiſh polity, is the people's choice of their repreſentatives in parliament. (See PARLIAMENT.) In this conſiſts the exerciſe of the democratical part of our conſtitution: for in a democracy there can be no exerciſe of ſovereignty but by ſuffrage, which is the declaration of the people's will. In all democracies, therefore, it is of the utmoſt importance to regulate by whom, and in what manner, the ſuffrages are to be given. And the Athenians were ſo juſtly jealous of this prerogative, that a ſtranger, who interfered in the aſſemblies of the people, was puniſhed by their laws with death; becauſe ſuch a man was eſteemed guilty of high treaſon, by uſurping thoſe rights of ſovereignty to which he had no title. In Britain, where the people do not debate in a collective body, but by repreſentation, the exerciſe of this ſovereignty conſiſts in the choice of repreſentatives. The laws have therefore very ſtrictly guarded againſt uſurpation or abuſe of this power, by many ſalutary proviſions; which may be reduced to theſe three points, 1. The qualifications of the electors. 2. The qualifications of the elected. 3. The proceedings at elections.

Blackſtone's Comment.

(1.) As to the qualifications of the electors. The true reaſon of requiring any qualification, with regard to property, in voters, is to exclude ſuch perſons as are in ſo mean a ſituation, that they are eſteemed to have no will of their own. If theſe perſons had votes, they would be tempted to diſpoſe of them under ſome undue influence or other. This would give a great, an artful, or a wealthy man, a larger ſhare in elections than is conſiſtent with general liberty. If it were probable that every man would give his vote freely, and without influence of any kind; then, upon the true theory and genuine principles of liberty, every member of the community, however poor, ſhould have a vote in electing thoſe delegates to whoſe charge is committed the diſpoſal of his property, his liberty, and his life. But ſince that can hardly be expected in perſons of indigent fortunes, or ſuch as are under the immediate dominion of others, all popular ſtates have been obliged to eſtabliſh certain qualifications; whereby ſome, who are ſuſpected to have no will of their own, are excluded from voting, in order to ſet other individuals, whoſe will may be ſuppoſed independent, more thoroughly upon a level with each other.

And this conſtitution of ſuffrages is framed upon a wiſer principle with us, than either of the methods of voting, by centuries, or by tribes, among the Romans. In the method by centuries, inſtituted by Servius Tullius, it was principally property, and not numbers, that turned the ſcale: in the method by tribes, gradually introduced by the tribunes of the people, numbers only were regarded, and property entirely overlooked. Hence the laws paſſed by the former method had uſually too great a tendency to aggrandize the patricians or rich nobles; and thoſe by the latter had too much of a levelling principle. Our conſtitution ſteers between the two extremes. Only ſuch are entirely excluded as can have no will of their own: there is hardly a free agent to be found, but what is intitled to a vote in ſome place or other in the kingdom. Nor is comparative wealth, or property, entirely diſregarded in elections; for though the richeſt man has only one vote at one place, yet, if his property be at all diffuſed, he has probably a right to vote at more places than one, and therefore has many repreſentatives. This is the ſpirit of our conſtitution; not that we aſſert it is in fact quite ſo perfect as we have endeavoured to deſcribe it; for if any alteration might be wiſhed or ſuggeſted in the preſent form of parliaments, it ſhould be in favour of a more complete repreſentation of the people.

But to return to the qualifications; and firſt thoſe of electors for knights of the ſhire. 1. By ſtatute 8 Hen. VI. c. 7. and 10 Hen. VI. c. 2. (amended by 14 Geo. III. c. 58.) the knights of the ſhire ſhall be choſen of people, whereof every man ſhall have freehold to the value of forty ſhillings by the year within the county; which (by ſubſequent ſtatutes) is to be clear of all charges and deductions, except parliamentary and parochial taxes. The knights of ſhires are the repreſentatives of the landholders, or landed intereſt of the kingdom: their electors muſt therefore have eſtates in lands or tenements within the county repreſented.

ſented. Theſe eſtates muſt be freehold, that is, for term of life at leaſt; becauſe beneficial leaſes for long terms of years were not in uſe at the making of theſe ſtatutes, and copyholders were then little better than villains, abſolutely dependent upon their lords. This freehold muſt be of 40 ſhillings annual value; becauſe that ſum would then, with proper induſtry, furniſh all the neceſſaries of life, and render the freeholder, if he pleaſed, an independent man: For Biſhop Fleetwood, in his *Chronicon Precioſum*, written at the beginning of the laſt century, has fully proved 40 ſhillings in the reign of Henry VI. to have been equal to 12 pounds per annum in the reign of Queen Anne; and, as the value of money is very conſiderably lowered ſince the biſhop wrote, we may fairly conclude, from this and other circumſtances, that what was equivalent to 12 pounds in his days, is equivalent to 20 at preſent. The other leſs important qualifications of the electors for counties in England and Wales may be collected from the ſtatutes cited below (A); which direct, 2. That no perſon under 21 years of age ſhall be capable of voting for any member. This extends to all ſorts of members as well for boroughs as counties; as does alſo the next, viz. 3. That no perſon convicted of perjury, or ſubornation of perjury, ſhall be capable of voting in any election. 4. That no perſon ſhall vote in right of any freehold, granted to him fraudulently, to qualify him to vote. Fraudulent grants are ſuch as contain an agreement to re-convey, or to defeat the eſtate granted; which agreements are made void, and the eſtate is abſolutely veſted in the perſon to whom it is ſo granted. And, to guard the better againſt ſuch frauds, it is further provided, 5. That every voter ſhall have been in the actual poſſeſſion, or receipt of the profits, of his freehold to his own uſe for 12 kalendar months before; except it came to him by deſcent, marriage, marriage ſettlement, will, or promotion to a benefice or office. 6. That no perſon ſhall vote in reſpect of an annuity or rent-charge, unleſs regiſtered with the clerk of the peace 12 kalendar months before. 7. That in mortgaged or truſt eſtates, the perſon in poſſeſſion, under the above-mentioned reſtrictions, ſhall have the vote. 8. That only one perſon ſhall be admitted to vote for any one houſe or tenement, to prevent the ſplitting of freeholds. 9. That no eſtate ſhall qualify a voter, unleſs the eſtate has been aſſeſſed to ſome land-tax aid, at leaſt 12 months before the election. 10. That no tenant by copy of court-roll ſhall be permitted to vote as a freeholder. Thus much for the electors in counties.

As for the electors of citizens and burgeſſes, theſe are ſuppoſed to be the mercantile part or trading intereſt of this kingdom. But as trade is of a fluctuating nature, and ſeldom long fixed in a place, it was formerly left to the crown to ſummon, *pro re nata*, the moſt flouriſhing towns to ſend repreſentatives to parliament. So that as towns increaſed in trade, and grew populous, they were admitted to a ſhare in the legiſlature. But the misfortune is, that the deſerted boroughs continued to be ſummoned, as well as thoſe to whom their trade and inhabitants were transferred; except a few which petitioned to be eaſed of the expence, then uſual, of maintaining their members: four ſhillings a-day being allowed for a knight of the ſhire, and two ſhillings for a citizen or burgeſs; which was the rate of wages eſtabliſhed in the reign of Edward III. Hence the members for boroughs now bear above a quadruple proportion to thoſe for counties; and the number of parliament men is increaſed ſince Forteſcue's times, in the reign of Henry VI. from 300 to upwards of 500, excluſive of thoſe for Scotland. The univerſities were, in general, not empowered to ſend burgeſſes to parliament; though once, in 28 Edw. I. when a parliament was ſummoned to conſider of the king's right to Scotland, there were iſſued writs, which required the univerſity of Oxford to ſend up four or five, and that of Cambridge two or three, of their moſt diſcreet and learned lawyers for that purpoſe. But it was King James I. who indulged them with the permanent privilege to ſend conſtantly two of their own body; to ſerve for thoſe ſtudents who, though uſeful members of the community, were neither concerned in the landed nor the trading intereſt; and to protect in the legiſlature the rights of the republic of letters. The right of election in boroughs is various, depending entirely on the ſeveral charters, cuſtoms, and conſtitutions of the reſpective places; which has occaſioned infinite diſputes; though now, by ſtatute 2 Geo. II. c. 24. the right of voting for the future ſhall be allowed according to the laſt determination of the houſe of commons concerning it; and, by ſtatute 3 Geo. III. c. 15. no freeman of any city or borough (other than ſuch as claim by birth, marriage, or ſervitude) ſhall be intitled to vote therein, unleſs he hath been admitted to his freedom 12 kalendar months before.

(2.) Next, as to the qualifications of perſons to be *elected* members of the houſe of commons. Some of theſe depend upon the law and cuſtom of parliaments, delared by the houſe of commons; others upon certain ſtatutes. And from theſe it appears, 1. That they muſt not be aliens born or minors. 2. That they muſt not be any of the 12 judges, becauſe they ſit in the lords' houſe; nor of the clergy, for they ſit in the convocation; nor perſons attainted of treaſon, or felony, for they are unfit to ſit anywhere. 3. That ſheriffs of counties, and mayors and bailiffs of boroughs, are not eligible in their reſpective juriſdictions, as being returning officers; but that ſheriffs of one county are elligible to be knights of another. 4. That, in ſtrictneſs, all members ought to have been inhabitants of the places for which they are choſen; but this, having been long diſregarded, was at length entirely repealed by ſtatute 14 Geo. III. c. 58. 5. That no perſons concerned in the management of any duties or taxes created ſince 1692, except the commiſſioners of the treaſury, nor any of the officers following (viz. commiſſioners of prizes, tranſports, ſick and wounded, wine licenſes, navy, and victualling; ſecretaries or receivers of prizes; comptrollers of the army accounts; agents for regiments; governors of plantations, and their

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(A) 7 and 8 Will. III. c. 25. 10 Ann. c. 23. 2 Geo. II. c. 21. 18 Geo. II. c. 18. 31 Geo. II. c. 14. 3 Geo. III. c. 24.

their deputies; officers of Minorca or Gibraltar; officers of the exciſe and cuſtoms; clerks or deputies in the ſeveral offices of the treaſury, exchequer, navy, victualling, admiralty, pay of the army or navy, ſecretaries of ſtate, ſalt, ſtamps, appeals, wine-licenſes, hackney-coaches, hawkers, and pedlars), nor any perſons that hold any new office under the crown created ſince 1705, are capable of being elected or ſitting as members. 6. That no perſon having a penſion under the crown during pleaſure, or for any term of years, is capable of being elected or ſitting. 7. That if any member accepts an office under the crown, except an officer in the army or navy accepting a new commiſſion, his ſeat is void; but ſuch member is capable of being re-elected. 8. That all knights of the ſhire ſhall be actual knights, or ſuch notable eſquires and gentlemen as have eſtates ſufficient to be knights, and by no means of the degree of yeomen. This is reduced to a ſtill greater certainty, by ordaining, 9. That every knight of a ſhire ſhall have a clear eſtate of freehold or copyhold to the value of 600l. per annum, and every citizen and burgeſs to the value of 300l.: except the eldeſt ſons of peers and of perſons qualified to be knights of ſhires, and except the members for the two univerſities; which ſomewhat balances the aſcendant which the boroughs have gained over the counties, by obliging the trading intereſt to make choice of landed men: and of this qualification the member muſt make oath, and give in the particulars in writing, at the time of his taking his ſeat. But, ſubject to theſe ſtanding reſtrictions and diſqualifications, every ſubject of the realm is eligible of common right: though there are inſtances, wherein perſons in particular circumſtances have forfeited that common right, and have been declared ineligible *for that parliament*, by a vote of the houſe of commons, or *for ever*, by an act of the legiſlature. But it was an unconſtitutional prohibition, which was grounded on an ordinance of the houſe of *lords*, and inſerted in the *king's* writs, for the parliament holden at Coventry, 6 Hen. IV. that no apprentice or other man of the law ſhould be elected a knight for the ſhire therein: in return for which, our lawbooks and hiſtorians have branded this parliament with the name of *parliamentum indoctum*, or the lack-learning parliament; and Sir Edward Coke obſerves with ſome ſpleen, that there was never a good law made thereat.

(3.) The third point, regarding elections, is the method of proceeding therein. This is alſo regulated by the law of parliament, and the ſeveral ſtatutes referred to in the margin below (B); all which we ſhall blend together, and extract out of them a ſummary account of the method of proceeding to elections.

As ſoon as the parliament is ſummoned, the lord chancellor (or if a vacancy happens during the ſitting of parliament, the ſpeaker, by order of the houſe, and without ſuch order if a vacancy happens by death in the time of a receſs for upwards of 20 days) ſends his warrant to the clerk of the crown in chancery; who thereupon iſſues out writs to the ſheriff of every county, for the election of all the members to ſerve for that county, and every city and borough therein. Within three days after the receipt of this writ, the ſheriff is to ſend his precept, under his ſeal, to the proper returning officers of the cities and boroughs, commanding them to elect their members: and the ſaid returning officers are to proceed to election within eight days from the receipt of the precept, giving four days notice of the ſame; and to return the perſons choſen, together with the precept, to the ſheriff.

But elections of knights of the ſhire muſt be proceeded to by the ſheriffs themſelves in perſon, at the next county-court that ſhall happen after the delivery of the writ. The county court is a court held every month or oftener by the ſheriff, intended to try little cauſes not exceeding the value of 40s. in what part of the county he pleaſes to appoint for that purpoſe: but for the election of knights of the ſhire, it muſt be held at the moſt uſual place. If the county-court falls upon the day of delivering the writ, or within ſix days after, the ſheriff may adjourn the court and election to ſome other convenient time, not longer than 16 days, nor ſhorter than 10: but he cannot alter the place, without the conſent of all the candidates; and, in all ſuch caſes, 10 days public notice muſt be given of the time and place of the election.

And, as it is eſſential to the very being of parliament that elections ſhould be abſolutely free, therefore all undue influences upon the electors are illegal, and ſtrongly prohibited. For Mr Locke ranks it among thoſe breaches of truſt in the executive magiſtrate, which, according to his notions, amount to a diſſolution of the government, "if he employs the force, treaſure, and offices of the ſociety to corrupt the repreſentatives, or openly to pre-engage the electors, and preſcribe what manner of perſons ſhall be choſen: For thus to regulate candidates and electors, and new-model the ways of election, what is it (ſays he) but to cut up the government by the roots and poiſon the very fountain of public ſecurity?" As ſoon, therefore, as the time and place of election, either in counties or boroughs, are fixed, all ſoldiers quartered in the place are to remove, at leaſt one day before the election, to the diſtance of two miles or more; and not to return till one day after the poll is ended. Riots likewiſe have been frequently determined to make an election void. By vote alſo of the houſe of commons, to whom alone belongs the power of determining conteſted elections, no lord of parliament, or lord-lieutenant of a county, hath any right to interfere in the election of commoners; and, by ſtatute, the lord warden of the cinque-ports ſhall not recommend any members there. If any officer of the exciſe, cuſtoms, ſtamps, or certain other branches of the revenue, preſumes to intermeddle in elections, by perſuading any voter or diſſuading him, he forfeits 100l. and is diſabled to hold any office.

(B) 7 Hen. IV. c. 15. 8 Hen. VI. c. 7. 23 Hen. VI. c. 14. 1 W. & M. ſt. 1. c. 2. 2 W. & M. ſt. 1. c. 7. 5 and 6 W. & M. c. 20. 7 W. III. c. 4. 7 and 8 W. III. c. 7. and c. 25. 10 & 11 W. III. c. 7. 12 and 13 W. III. c. 10. 6 Ann. c. 23. 9 Ann. c. 5. 10 Ann. c. 19. and c. 33. 2 Geo. II. c. 24. 8. Geo. II. c. 30. 18 Geo. II. c. 18. 19 Geo. II. c. 28. 10 Geo. III. c. 16. 11 Geo. III. c. 42. 14 Geo. III. c. 15.

Thus are the electors of one branch of the legiſlature ſecured from any undue influence from either of the other two, and from all external violence and compulſion. But the greateſt danger is that in which themſelves co-operate, by the infamous practice of bribery and corruption. To prevent which it is enacted, that no candidate ſhall, after the date (uſually called the *teſte*) of the writs, or after the vacancy, give any money or entertainment to his electors, or promiſe to give any, either to particular perſons, or to the place in general, in order to his being elected; on pain of being incapable to ſerve for that place in parliament. And if any money, gift, office, employment, or reward be given, or promiſed to be given, to any voter, at any time, in order to influence him to give or withhold his vote, as well he that takes as he that offers ſuch bribe forfeits 500l. and is for ever diſabled from voting and holding any office in any corporation; unleſs, before conviction, he will diſcover ſome other offender of the ſame kind, and then he is indemnified for his own offence. The firſt inſtance that occurs of election bribery, was ſo early as 13 Eliz. when one Thomas Longe (being a ſimple man, and of ſmall capacity to ſerve in parliament) acknowledged that he had given the returning officer and others of the borough for which he was choſen four pounds to be returned member, and was for that premium elected. But for this offence the borough was amerced, the member was removed, and the officer fined and impriſoned. But as this practice hath ſince taken much deeper and more univerſal root, it hath occaſioned the making of theſe wholeſome ſtatutes; to complete the efficacy of which, there is nothing wanting but reſolution and integrity to put them in ſtrict execution.

Undue influence being thus guarded againſt, the election is to be proceeded to on the day appointed; the ſheriff or other returning officer firſt taking an oath againſt bribery, and for the due execution of his office. The candidates likewiſe, if required, muſt ſwear to their qualification, and the electors in counties to theirs; and the electors both in counties and boroughs are alſo compellable to take the oath of abjuration, and that againſt bribery and corruption. And it might not be amiſs, if the members elected were bound to take the latter oath as well as the former; which, in all probability, would be much more effectual than adminiſtering it only to the electors.

The election being cloſed, the returning officer in boroughs returns his precept to the ſheriff, with the perſons elected by the majority: and the ſheriff returns the whole, together with the writ for the county and the knights elected thereupon, to the clerk of the crown in chancery; before the day of meeting, if it be a new parliament, or within 14 days after the election, if it be an occaſional vacancy; and this under penalty of 500l. If the ſheriff does not return ſuch knights only as are duly elected, he forfeits, by the old ſtatutes of Henry VI. 100l.; and the returning officer in boroughs, for a like falſe return, 40l.; and they are beſides liable to an action, in which double damages ſhall be recovered, by the later ſtatutes of King William: and any perſon bribing the returning officer ſhall alſo forfeit 300l. But the members returned by him are the ſitting members, until the houſe of commons, upon petition, ſhall adjudge the return to be falſe and illegal. The form and manner of proceeding upon ſuch petition are now regulated by ſtatute 10 Geo. III. c. 16. (amended by 11 Geo. III. c. 42. and made perpetual by 14 Geo. III. c. 15.), which directs the method of chooſing by lot a ſelect committee of 15 members, who are ſworn well and truly to try the ſame, and a true judgment to give, according to the evidence.

Election of Scots Peers. See Lords.

Election of Eccleſiaſtical Perſons. Elections for the dignities of the church ought to be free, according to the ſtat. 9. Ed. II. cap. 14. If any perſons, that have a voice in elections, take any reward for an election in any church, college, ſchool, &c. the election ſhall be void. And if any perſons of ſuch ſocieties reſign their places to others for reward, they incur a forfeiture of double the ſum; and both the parties are rendered incapable of the place. Stat. 31 Eliz. cap. 6.

Election of a Verderor of the Foreſt (electione viridariorum foreſtæ), in *Law*, a writ that lies for the choice of a verderor, where any of the verderors of the foreſt are dead, or removed from their offices. This writ is directed to the ſheriff, and the verderor is to be elected by the freeholders of the county, in the ſame manner as coroners. New. Nat. Brev. 366.

Election is alſo the ſtate of a perſon who is left to his own free will, to take or do either one thing or another, which he pleaſes. See Liberty.

Election, in *Theology*, ſignifies the choice which God, of his good pleaſure, makes of angels or men, for the objects of mercy and grace.

The election of the Jews was the choice God made of that people to be more immediataly attached to his worſhip and ſervice, and for the Meſſiah to be born of them. And thus particular nations were elected to the participation of the outward bleſſings of Chriſtianity.

Election alſo, in the language of ſome divines, ſignifies a predeſtination to grace and glory, and ſometimes to glory only. And it has been enjoined as an article of faith, that predeſtination to grace is gratuitous, merely and ſimply ſo; *gratia, quia gratis data.* But the divines are much divided as to the point, whether election to glory be gratuitous, or whether it ſuppoſes obedience and good works, i. e. whether it be before or after the proviſion of our obedience. See Grace and Reprobation.

ELECTIVE, ſomething that is done, or paſſes, by election. See Elector.

Some benefices are elective, others collative. Municipal offices in England are generally elective; in Spain, venal. Poland is an elective kingdom.

Elective Attraction. See Chemistry *Index*.

ELECTOR, a perſon who has a right to elect or chooſe another to an office, honour, &c. See Election.

Elector is particularly, and by way of eminence, applied to thoſe princes of Germany in whom lies the right of electing the emperor; being all ſovereign princes, and the principal members of the empire.

The electoral college, conſiſting of all the electors of the empire, is the moſt illuſtrious and auguſt body in Europe. Bellarmine and Baronius attribute the inſtitution of it to Pope Gregory V. and the emperor Otho

tho III. in the tenth century; of which opinion are the generality of hiſtorians, and particularly the canoniſts: however, the number of electors was unſettled, at leaſt, till the 13th century. In 1356 Charles IV. by the golden bull, fixed the number of electors to ſeven; three eccleſiaſtics, viz. the archbiſhops of Mentz, Treves, and Cologne; and four ſecular, viz. the king of Bohemia, count Palatine of the Rhine, duke of Saxony, and marquis of Brandenburg. In 1648 this order was changed, the duke of Bavaria being put in the place of the count Palatine, who having accepted the crown of Bohemia was outlawed by the emperor; but being at length reſtored, an eighth electorate was erected for the duke of Bavaria. In 1692, a ninth electorate was created, by the emperor Leopold, in favour of the duke of Hanover, of the houſe of Brunſwic Lunenburg.

There is this difference between the ſecular and eccleſiaſtical electors, that the firſt have an active and paſſive voice, that is, may chooſe and be choſen; the laſt an active only. The three archbiſhops are to be 30 years old before they can be advanced to the dignity; the ſeculars 18, before they can perform the office themſelves. Theſe laſt have each their vicars, who officiate in their abſence.

Beſides the power of chooſing an emperor, the electors have alſo that of capitulating with and depoſing him; ſo that, if there be one ſuffrage wanting, a proteſt may be entered againſt the proceedings. By the right of capitulation, they attribute to themſelves great privileges, as making of war, coining, and taking care of the public intereſt and ſecurity of the ſtates; and the emperor promiſes, upon oath, to receive the empire upon theſe conditions.

The electors have precedence of all other princes of the empire, even of cardinals and kings; and are addreſſed under the title of *electoral highneſs*.

Their ſeveral functions are as follow. The elector of Mentz is chancellor of Germany, convokes the ſtates, and gives his vote before any of the reſt. The elector of Cologne is grand chancellor of Italy, and conſecrates the emperor. The elector of Treves is chancellor of the Gauls, and confers impoſition of hands upon the emperor. The count Palatine of the Rhine is great treaſurer of the empire, and preſents the emperor with a globe at his coronation. The elector of Bavaria is great maſter of the imperial palace, and carries the golden apple. The marquis of Brandenburg is grand-chamberlain, and puts the ring on the emperor's finger. The elector of Saxony is grand marſhal, and gives the ſword to the emperor. The king of Bohemia is grand butler, and puts Charlemagne's crown on the emperor's head. Laſtly, the elector of Hanover, now king of Great Britain, is arch treaſurer, though firſt erected under the title of *ſtandard-bearer* of the empire.

ELECTORATE, a term uſed as well to ſignify the dignity of, as the territories belonging to, any of the electors of Germany; ſuch are Bavaria, Saxony, &c. See ELECTOR.

ELECTRIC, derived from ηλεκτρον, "amber," in phyſics, is a term applied to thoſe ſubſtances, in which the electric fluid is capable of being excited, and accumulated without tranſmitting it, and therefore called *non-conductors*. See ELECTRICITY.

ELECTRICITY.

INTRODUCTION.

General Principles.

1 General idea of electricity.

WHEN a glaſs tube of conſiderable ſize, perfectly clean and dry, is rubbed briſkly with a dry hand, and immediately held over ſmall pieces of paper, ſtraws, feathers, or other light bodies, it will attract them, and after retaining them in contact with it for ſome time, repel them; and this attraction and repulſion will be alternately repeated ſeveral times.

If after rubbing the tube, the knuckle be preſented to the cloſed end, a ſnapping noiſe will be heard, and the finger will receive a ſlight ſhock. When this experiment is made in the dark, a luminous ſpark will appear at the moment the ſnap is heard, between the finger and the tube.

2 Electrics.

Many other ſubſtances poſſeſs the property of attracting light bodies and emitting ſparks, when rubbed with certain other ſubſtances, as amber, ſealing-wax, roſin, &c. As amber was firſt obſerved to poſſeſs them, the bodies which are capable of exhibiting ſimilar appearances have been termed ELECTRICS, from ηλεκτρον, *amber;* and the ſcience which illuſtrates and explains theſe phenomena is denominated ELECTRICITY (A).

3 Electric power.

We ſhall not at preſent attempt any inquiry into the cauſe of theſe phenomena, but ſhall content ourſelves with calling the power by which they are produced, the *electric power*, reſerving any inveſtigation of the nature of this power for a future part of this article, in which we ſhall treat of the *theory* of electricity. The term *electricity*, which is moſt properly applicable to the ſcience, is alſo ſometimes applied to the cauſe of the phenomena, or what we here call the *electric power*.

4 Excitation.

When *electrics* are made, by rubbing, to ſhew the action of the electric power, they are ſaid to be *excited*.

5 Non-electrics or conductors.

There are many ſubſtances which are incapable of being excited, ſo as to produce electrical appearances, and are therefore *non-electrics;* but which being placed near or in contact with an excited electric, receive from

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(A) The attracting power of amber when rubbed, is ſaid to have been known to Thales the Mileſian philoſopher, 600 years before Chriſt.

General Principles.

from this a portion of the *electric power*, and are thus made capable of producing the ſame appearance as the electric. Thus if a metallic rod or wire pointed at one end and rounded at the other, be attached by the pointed extremity to an excited *electric*, or even placed very near this, the rounded extremity will attract light bodies, and emit ſparks. As theſe ſubſtances are found to convey or *conduct* the *electric power* to any diſtance in proportion to their length, they are called *conductors*.

It is found that all bodies in nature are either *electrics* or *conductors*. Neither of theſe claſſes of bodies are, however, perfect electrics or conductors, as there are few electrics which may not under ſome circumſtances be made to act as conductors, and on the other hand, many conductors may be ſo far excited as to become in ſome meaſure electrics *per ſe* (B). The following table exhibits the electrics and conductors arranged according to their degree of electrical or conducting power.

Electrics.

Glaſs and all vitrifications, even the metallic vitrifications.

All precious ſtones, of which the moſt tranſparent are the beſt.

Amber.

Sulphur.

All reſinous ſuſtances.

Wax.

Silk.

Cotton.

Several dry and external animal ſubſtances, as feathers, wool, hair, &c.

Paper.

White ſugar, and ſugar-candy.

Air, and other permanently elaſtic fluids.

Oils.

Dry and complete oxides of metallic ſubſtances.

The aſhes of animal and vegetable ſubſtances.

Dry vegetable ſubſtances.

Moſt hard ſtones, of which the hardeſt are the beſt.

Conductors.

Gold.

Silver.

Copper.

Platina.

Braſs.

Iron.

Tin.

Quickſilver.

Lead.

Semi-metals, more or leſs.

Metallic ores, more or leſs.

Charcoal, either of animal or of vegetable ſubſtances.

The fluids of an animal body.

Water (eſpecially ſalt water), and all fluids, excepting the aërial, and oils.

The effluvia of flaming bodies.

Congealed water, viz. ice or ſnow.

Moſt ſaline ſubſtances, of which the metallic ſalts are the beſt.

Several earthy or ſtony ſubſtances.

Smoke.

The vapour of hot water.

Electricity pervades alſo ſuch a vacuum, or abſence of air, as is cauſed by the beſt air-pump; but not the perfect abſence of air, or the torricellian vacuum, formed by boiling the quickſilver in a barometer tube.

Cavallo's Philoſophy, vol. 3.

Many of the ſubſtances given in the above table are found to change their nature under certain circumſtances. Thus, among the electrics, glaſs heated to redneſs, melted reſins, baked wood when very hot, and heated air, are tolerably good conductors; and glaſs, which is uſually the beſt electric, is ſometimes from cauſes which have not been well aſcertained a very bad electric. The excitability of glaſs veſſels is found to differ according to the degree of rarefaction of the included air; when this is rarefied as much as poſſible, the external ſurface of the veſſel cannot be excited, while the internal ſurface exhibits ſtrong marks of *electric power;* but when the included air is conſiderably condenſed, the internal ſurface ſhews no marks of electric power, while the external is much more excitable than uſual.

Among the conductors, the conducting power of charcoal varies in proportion to the degree of heat to which it has been expoſed in the making, as, when imperfectly burned, it is a bad conductor. Indeed it is worth remarking here, that wood is capable of being made an electric or a conductor ſeveral times alternately according to its ſtate. When freſh cut, it is a good *conductor:* thoroughly dried by baking, it becomes, as we have ſeen an *electric;* burned to charcoal, it is again a conductor; but when reduced to aſhes, it is once more made an *electric*.

Ice (C) is placed among the conductors: but in an experiment of M. Achard, it appeared that when diſtilled water was gradually frozen, ſo that one ſide of the veſſel retained it fluid, and therefore permitted the air to eſcape, the ice thus produced would not conduct, but on the contrary became a very good electric, and was employed as ſuch. Snow is a much worſe conductor than ice. Water is a conductor, and ſo are the ſecondary ſalts; it is found that when water is impregnated with a ſalt, its conducting power is much increaſed.

We have, after Mr Cavallo, placed the *ſalts* among conductors; but in ſtrict propriety, this conducting power muſt be confined to ſalts in the ſtate of cryſtals, as it has been proved by deciſive experiments, that ſalts,

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(B) The difference between electrics and conductors was firſt obſerved by Mr Stephen Grey in 1759, but the terms *conductor* and *electric per ſe*, were firſt employed in this preſent ſenſe by Dr Deſaguliers.

(C) The conducting power of *common* ice was firſt ſhewn by M. Jallabert, profeſſor of philoſophy at Geneva; there ſeem, however, to have been various opinions reſpecting this facts till it was fully aſcertained by Dr Prieſtley. Vid. *Prieſtley's Hiſtory of Electricity*, Part viii. ſect. 4.

General Principles.

ſalts, when deprived of their water of cryſtallization, become non-conductors. The conducting power of cryſtallized ſalts is therefore probably owing to the water which they contain.

6 Inſulation.

Electrics are called *non-conductors*, as they do not readily tranſmit *electric power;* they may hence be employed to check the paſſage of this power, or to confine its influence. When a body communicates with a conducting ſubſtance, as the earth, a table, the human body, &c. the electric power eaſily paſſes off; but when it is ſupported by an electric, the power may be retained for a conſiderable time. In this latter caſe the body is ſaid to be *inſulated*.

We have ſeen (1, 3), that fire or light appears to iſſue from an excited electric; and this appearance is ſtronger in proportion to the ſize of the electric, and the degree of friction which it has undergone. When a rounded body, as the knuckle or a metallic ball, is preſented to the excited electric, the fire appears to dart from it in a ſpark; but if the preſented body be pointed, the fire will appear to iſſue in a ſtream compoſed of luminous rays. Theſe rays will take a different direction, according to the ſubſtance with which the electric is rubbed, and other circumſtances which will be explained hereafter. In the caſe of the glaſs tube rubbed with the hand, when a pointed body, as a needle, or wire, is preſented to the tube, the luminous rays will appear like a *ſtar* around the point. The ſame appearance will take place on preſenting a point to a ſtick of ſealing-wax rubbed with any metallic body, as a piece of tin foil; but when the ſealing-wax is rubbed with a piece of woollen cloth, the rays will appear to iſſue from the point in a *pencil* diverging towards the wax. In ſome experiments which will afterwards be deſcribed, the ſtream of fire appears in an evident current in a direction from the electric in ſome caſes, as in the tube excited as above, and towards the electric in others, as in the wax rubbed with the woollen cloth.

7 Poſitive and negative electricity,

Theſe different appearances have been ſuppoſed owing to two different ſtates of the *electric power*, and theſe ſtates have been called the two electricities. As in the former caſe, the fire ſeems to flow *from* the glaſs *into* the metallic body, as if there was an *exceſs* in the former, the glaſs is ſaid to be electrified *plus*, or *poſitively*, and this is called *poſitive electricity*. In the latter caſe, as the ſtream appears to flow *from* the point *into* the ſealing-wax, as if there were a *deficiency* in the latter, the ſealing-wax is ſaid to be electrified *minus*, or *negatively*, and this is called the *negative electricity*:

8 or vitreous and reſinous electricity.

As when glaſs is rubbed with moſt ſubſtances, *poſitive*, electricity is excited, and *negative* when reſinous bodies are rubbed with moſt ſubſtances, the former is often called *vitreous*, and the latter *reſinous* electricity.

The difference of theſe two ſtates of the electric power may be further illuſtrated by the following ſimple experiment.

Plate CLXXXVII

Let a ſtem of glaſs (A, B. fig. 1.) be fixed in a wooden pedeſtal C. Through the upper extremity A, paſs a wire A, D, with a rounded end at D, and from this end ſuſpend two very fine ſilken threads *a*, *b*. Theſe threads in the uſual ſtate of the inſtrument will hang in the parallel poſition *a*, *b*, but if the end of the wire to which they are attached be preſented to the excited tube, the threads will diverge from each other, and take a poſition as at *c*, *d*. If in this diverging ſtate they are preſented to an excited ſtick of ſealing-wax, they will collapſe into their original poſition. Again, the threads preſented firſt to the excited ſealing-wax will diverge, but preſented in this ſtate to the excited tube will collapſe, thus ſhowing that theſe two ſtates are oppoſite to each other, each deſtroying the effect produced by the other.

General Principles.

The following table ſhows what kind of electricity will be excited by rubbing various electrics with different bodies.

The back of a cat	Poſitive	Every ſubſtance with which it has been hitherto tried.
Smooth glaſs	Poſitive	Every ſubſtance hitherto tried, except the back of a cat.
Rough glaſs	Poſitive	Dry oiled ſilk, ſulphur, metals.
	Negative	Woollen cloth, quills, wood, paper, ſealing-wax, white-wax, the human hand.
Tourmalin	Poſitive	Amber, air.
	Negative	Diamond, the human hand.
Hare's ſkin	Poſitive	Metals, ſilks, loadſtone, leather, hand, paper, baked wood.
	Negative	Other finer furs.
White ſilk	Poſitive	Black ſilk, metals, black cloth.
	Negative	Paper, hand, hares and weaſels ſkin.
Black ſilk	Poſitive	Sealing-wax.
	Negative	Hares, weaſels, and ferrets ſkin, loadſtone, braſs, ſilver, iron, hand.
Sealing-wax	Poſitive	Metals.
	Negative	Hares, weaſels, and ferrets ſkin, hand, leather, woollen, cloth, paper.
Baked wood	Poſitive	Silk
	Negative	Flannel.

9 Electrified bodies.

It appears from (3) that the power of producing electrical appearances may be communicated from an excited electric to a conductor. The more perfect the conductor, the more eaſily does it receive the electric power. Electrics may alſo be made to receive this power from excited electrics, but it is communicated to theſe with more difficulty than to conductors. When any body, whether electric or conductor, is made to exhibit electrical phenomena, either by being excited, or by communication, it is ſaid to be *electrified*.

PART I.

OF THE GENERAL PHENOMENA OF EXCITED ELECTRICITY.

General Phenomena.

WHEN an electric is once excited, it will retain the electric power for a longer or ſhorter time according to its ſituation and nature. If it communicates freely with conductors, it will loſe it ſooner in proportion as theſe are more perfect; but if it be *inſulated*, it will continue in an electrified ſtate for a conſiderable time.

10 Modes of exciting electrics.

Electrics may be excited in various modes; the greateſt number of them by friction, as glaſs, precious ſtones, ſilk, ſulphur, ſealing-wax, amber, &c.; ſome by melting, and being allowed to cool, as ſulphur, wax; or ſimply by heating and cooling, as the tourmalin. We ſhall here give an account of the general appearances exhibited by the principal electrics when excited in theſe ſeveral modes.

11 Friction.

Friction, as we have obſerved, is the more uſual method of exciting electrics. Theſe may be rubbed either by other electrics, or by conductors, but in ſome caſes they are beſt excited by being rubbed with the moſt perfect conductors. Thus glaſs rubbed with ſilk, exhibits ſigns of electricity, but theſe are much ſtronger if the ſilk be covered with ſome metallic ſubſtance, as an amalgam of zinc. Duſt or moiſture is found very much to diminiſh the excitability of electrics; but oil, or any fat ſubſtance increaſes it. The appearances ſhown by electrics excited by friction, differ ſomewhat according to the nature of the electric, and the ſubſtance employed as a rubber; we ſhall deſcribe the moſt remarkable of them, as they will ſerve hereafter to illuſtrate and explain the experiments which are to be introduced in the following parts of this article.

Chap. I. *Of the Phenomena produced by excited glaſs.*

12 Phenomena from excited glaſs.

Dr William Gilbert, a native of Colcheſter in Eſſex, and a phyſician in London, who publiſhed in the year 1600 a valuable treatiſe "*De Magnete*," was the firſt, we believe, who obſerved the electrical property of glaſs when rubbed; but he diſcovered little more than that like amber it attracted and repelled light bodies. He found that the moſt tranſparent glaſs was the beſt electric *. In the beginning of the eighteenth century. Mr Hawkeſbee, to whom electricity is indebted for many improvements, made the firſt rational experiments on the electric power of glaſs. He contrived to fix a hollow globe of glaſs in a wooden frame, ſo that it could be whirled round while he rubbed it by applying his dry hand to the ſurface. He obſerved that when the air within the globe was conſiderably rarefied, a ſtrong light appeared in the inſide on applying his hand to the globe, and when the air was reſtored to its natural denſity, a light appeared alſo on the outſide, appearing as if ſticking to his fingers or other bodies held near the globe.

13 Mr Hawkeſbee's experiments.

Having exhauſted another globe of glaſs, he obſerved, that on bringing this near his excited globe, a light appeared within the former, and became very brilliant if the exhauſted globe was kept in motion, but died away in a ſhort time if it was ſuffered to remain at reſt.

He coated more than half of the inſide of a globe with ſealing-wax of various thickneſs, and after exhauſting the globe, he ſet it in motion. On applying his hand as a rubber, he was ſurpriſed to ſee the exact ſhape of his hand appearing on the concave ſurface of the wax, and that even where the coating of wax was interpoſed between his hand and the oppoſite ſide, though the wax was in ſome places an eighth of an inch in thickneſs.

Pitch or common ſulphur melted anſwered as well as wax, but he could not produce theſe appearances by uſing melted flowers of ſulphur. When he employed a very thick coating of common ſulphur, he obſerved that there was a much greater light within the globe; but he could not ſo eaſily diſtinguiſh the figure of his hands.

On admitting a ſmall quantity of air into the globe, the light diminiſhed, and on the coating of ſealing wax it entirely diſappeared. While the globe continued exhauſted, the coated part of it ſhowed ſome attraction for light bodies, but if there was no wax, the globe would not attract at all; on admitting the air, the power of attraction was greater on the coated than on the uncoated part. *

Glaſs in any form is capable of excitation, but it is more eaſy, as well as more convenient, to employ a veſſel or plate of glaſs than a ſolid rod or maſs of that ſubſtance; and the thinner the veſſel or plate is, the more eaſily is it excited. When a tube, plate, or veſſel of glaſs is excited, it is found that one ſide is electrified poſitively and the other negatively. Both ſmooth and rough glaſs may be employed to produce electrical phenomena, but they require different rubbers. The beſt rubber for ſmooth glaſs is black oiled ſilk ſpread with an amalgam of zinc, made in the proportion of four or five parts of mercury to one of zinc. The beſt rubber for rough glaſs is ſoft new flannel. The amalgam of zinc may be moſt conveniently made in the following manner. Place the zinc over the fire in an iron ladle; and when the ladle is red hot, put a ſmall quantity of tallow or ſuet on the zinc, which will immediately melt. It is beſt not to allow the zinc to melt without the addition of ſome fatty matter, as this metal is very eaſily oxydated or calcined, and thus a great part of it would be rendered unfit for the required purpoſe; this inconvenience is prevented by the fat which covers the ſurface of the melted metal, and protects it from the action of the air. When the zinc is melted, add the mercury, previouſly heated to the degree of boiling water; ſtir the mixture a little, and allow it to cool. Laſtly, rub it well in a glaſs mortar, ſo as to unite the fat with it, which will prevent it from becoming hard by keeping, and will alſo preſerve it longer from oxidation.

Mr Canton, who was the firſt perſon that employed an amalgam to increaſe the effect of friction on glaſs tubes,

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* *Gilbert de Magnete*, ii. 2.

* *Phyſico-mechanical experiments*, p. 65.

tubes, uſed an amalgam of two parts of mercury and one of tin-foil, with the addition of a little chalk. Mr Wilcke found that a piece of woollen cloth ſpread with a little wax formed a very powerful rubber for ſmooth glaſs. The beſt rubber for rough glaſs is ſoft new flannel.

14
Mercurial phoſphorus.

It had been obſerved by Mr Hawkeſbee, that on ſhaking mercury in a glaſs veſſel, in the dark, a conſiderable light was produced, and that this was much more remarkable when the air in the veſſel was conſiderably rarefied. He called the light which he conceived to be emitted from the mercury, *mercurial phoſphorus*.

Mr Cavallo found that, by ſhaking mercury in a glaſs tube hermetically ſealed, and in which the air was pretty much rarefied, the tube was ſenſibly electrified on the outſide; but the electricity produced was not conſtant, nor in proportion to the agitation. From this obſervation he was led to make ſome experiments, the reſults of which are very curious.

15
Cavallo's experiments with glaſs tubes.

He prepared ſeveral tubes ſuch as are repreſented at fig. 2. Plate CLXXXVII. about 31 inches long, and ſomewhat leſs than half an inch in diameter and about one twentieth of an inch thick.

They were cloſed at one end, and contained each three fourths of an ounce of mercury, which being made to boil, the air within the tube was rarefied and the open end was then hermetically ſealed. Having made the tube clean and a little warm, he cauſed the mercury to flow from the one end to the other, by gently elevating and depreſſing either end, alternately, while the tube was held nearly in a horizontal poſition. The tube was thus rendered electrical, but ſo that the end where the mercury ſtood was electrified poſitively (D) and all the remaining part of the tube negatively. If the mercury was made to flow from the poſitive end to the negative, by elevating the former, the end to which it flowed became poſitive, while the reſt of the tube acquired a negative electricity; but if in elevating the poſitive end where the mercury ſtood, that end were not touched with the hand, it became negative only in a ſlight degree, and if the mercury was made to flow back to it, and again retire from it, ſtill without touching it, it became poſitive; whereas by touching it while elevating it, it was rendered ſtrongly negative. The electric power was always ſtrongeſt at the poſitive end. The electric power at either end was made much more apparent by coating each end for about two inches with tin foil, as repreſented in the figure, ſo that the tubes would ſometimes emit ſparks on being brought near a conductor. *

16
Durability of the electricity of glaſs.

We have ſeen (6) that when an electric is once excited, it retains the electric power for ſome time. Glaſs is one of the moſt remarkable electrics in this reſpect.

Mr Canton procured ſome very thin glaſs balls, about an inch and a half in diameter, with ſlender tubular ſtems of eight or nine inches in length. He electrified theſe balls in the inſide, or ſemi-poſitively, and then ſealed the ſtems hermetically. On examining them after ſome time, he found that they ſhowed no ſigns of electricity; but on holding them at a ſmall diſtance from the fire, they became ſtrongly electrical, and ſtill more ſo as they cooled. On repeatedly heating them, he found that the electric power diminiſhed, but it was not impaired by keeping them for a week under water. One of them which he had heated ſeveral times before immerſing it in water, and again ſeveral times after lying for a week in water, ſtill retained a conſiderable degree of electric power at the end of above a month; and even at the end of ſix years they had not entirely loſt it.

Mr Henley having electrified a ſmall bottle, obſerved that it ſhowed ſigns of electricity ſeventy days after, though it had ſtood all that time in a cupboard.

On the 5th February he excited a glaſs cylinder; and from that time till the 10th of March following, various methods were employed to deſtroy its electricity. Theſe always ſucceeded at the time, and the cylinder loſt all ſigns of electricity; but theſe ſigns returned again without any freſh excitation, and on the 10th of March the cylinder ſtill retained conſiderable electric power. The marks of electricity ſometimes became ſtronger or weaker, or even quite diſappeared and returned without any evident cauſe. The electricity was generally ſtrongeſt when the wind was northerly, or when it had returned after having been deſtroyed by flame; it was generally weakeſt when there was a fire in the room where it was kept, or when the door was left open. He repeated the excitation, but not always with the ſame ſucceſs; for ſome times the cylinder would loſe all ſigns of electricity in a fortnight, and at others in twelve hours, till it was again excited *.

Chap. II. *Of the Phenomena produced by excited Silk.*

Silk was firſt diſcovered to be an electric in the year 1729 by Mr Stephen Grey, while making experiments with his friend Mr Wheeler. Theſe gentlemen attempted to conduct the electric power to a great diſtance by means of ſilk lines, as Mr Grey had done before by means of packthread; but they were diſappointed, as they found that the ſilk refuſed to conduct,

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* *Cavallo's Electricity*, vol. ii. p. 69.

* *Phil. Tranſ.* lxxvii.

(D) The method of diſtinguiſhing between poſitive and negative electricity will be more fully explained hereafter, as well as the modes in which either may be produced at pleaſure. But it may be proper here to ſhow a ſimple mode of diſtinguiſhing theſe two ſtates of the electric power, which may be done by means of the inſtrument deſcribed in (8). The electricity ſhown by excited poliſhed glaſs was ſaid to be poſitive; and it appeared that the threads of the inſtrument ſeparated when brought near an excited tube, as alſo when brought near excited ſealing wax, the electricity of which is negative. If, therefore, when the threads are made to diverge by excited glaſs, they diverge ſtill farther, or remain ſtationary on being made to approach any other electrified body, the electricity of this laſt is *poſitive*; but if they collapſe, it is *negative*. Again if the threads, when made to diverge by excited ſealing wax, diverge ſtill farther, or remain ſtationary on being made to approach another electrified body, the electricity of this is *negative*; but if they collapſe, it is *poſitive*.

but ſeemed rather to retain the electric power; no experiments of any conſequence were however made on this ſubſtance, till 1759, when Mr Symmer preſented to the Royal Society a ſeries of obſervations which he had made on ſilk ſtockings.

He had been accuſtomed to wear two pairs of ſilk ſtockings; a black and a white. When theſe were put off both together, no ſigns of electricity appeared; but on pulling off the black ones from the white, he heard a ſnapping or crackling noiſe, and in the dark perceived ſparks of fire between them. To produce this and the following appearances in great perfection, it was only neceſſary to draw his hand ſeveral times backward and forward over his leg with the ſtocking upon it.

17
Strong attraction and repulſion between electrified ſtockings.

When the ſtockings were ſeparated and held at a diſtance from each other, both of them appeared to be highly excited; the white ſtocking poſitively, and the black negatively. While they were kept at a diſtance from each other, both of them appeared inflated to ſuch a degree, that they exhibited the entire ſhape of the leg. When two black or two white ſtockings were held in one hand, they would repel one another with conſiderable force, making an angle ſeemingly of 30 or 35 degrees. When a white and black ſtocking were preſented to each other, they were mutually attracted; and if permitted, would ruſh together with ſurpriſing violence. As they approached, the inflation gradually ſubſided, and their attraction of foreign objects diminiſhed, but their attraction of one another increaſed; when they actually met, they became flat, and joined cloſe together like as many folds of ſilk. When ſeparated again, their electric virtue did not ſeem to be in the leaſt impaired for having once met; and the ſame appearances would be exhibited by them for a conſiderable time. When the experiment was made with two black ſtockings in one hand, and two white ones in the other, they were thrown into a ſtrange agitation, owing to the attraction between thoſe of different colours, and the repulſion between thoſe of the ſame colour. This mixture of attractions and repulſions made the ſtockings catch at each other at greater diſtances than otherwiſe they would have done, and afforded a very curious ſpectacle.

When the ſtockings were ſuffered to meet, they ſtuck together with conſiderable force. At firſt Mr Symmer found they required from one to 12 ounces to ſeparate them. Another time they raiſed 17 ounces, which was 20 times the weight of the ſtocking that ſupported them; and this in a direction parallel to its ſurface. When one of the ſtockings was turned inſide out, and put within the other, it required 20 ounces to ſeparate them; though at that time ten ounces were ſufficient when applied externally. Getting the black ſtockings new dyed, and the white ones waſhed, and whitened in the fumes of ſulphur, and then putting them one within the other, with the rough ſides together, it required three pounds three ounces to ſeparate them. With ſtockings of a more ſubſtantial make, the coheſion was ſtill greater. When the white ſtocking was put within the black one, ſo that the outſide of the white was contiguous to the inſide of the black, they raiſed nine pounds wanting a few ounces; and when the two rough ſurfaces were contiguous, they raiſed 15 pounds one pennyweight and a half. Cutting off the ends of the thread and the tufts of ſilk which had been left in the inſide of the ſtockings, was found to be very unfavourable to theſe experiments.

Mr Symmer alſo obſerved, that pieces of white and black ſilk, when highly electrified, not only cohered with each other, but would alſo adhere to bodies with broad and even poliſhed ſurfaces, though theſe bodies were not electrified. This he diſcovered accidentally; having, without deſign, thrown a ſtocking out of his hand, which ſtuck to the paper-hangings of the room. He repeated the experiment, and found it would continue hanging near an hour. Having ſtuck up the black and white ſtockings in this manner, he came with another pair highly electrified; and applying the white to the black, and the black to the white, he carried them off from the wall, each of them hanging to that which had been brought to it. The ſame experiments held with the painted boards of the room, and likewiſe with the looking-glaſs, to the ſmooth ſurface of which both the white and the black ſilk appeared to adhere more tenaciouſly than to either of the former. *

18
Experiments on ribbons by Mr Cigna.

Similar experiments, but with a greater variety of circumſtances, were afterwards made by Mr Cigna of Turin, upon white and black ribbons. He took two white ſilk ribbons juſt dried at the fire, and extended them upon a ſmooth plain, whether a conducting or electric ſubſtance was a matter of indifference. He then drew over them the ſharp edge of an ivory ruler, and found that both ribbons had acquired electricity enough to adhere to the plain; though while they continued there, they ſhowed no other ſign of it. When taken up ſeparately, they were both negatively electrified, and would repel each other. In their ſeparation, electric ſparks were perceived between them; but when again put on the plain, or forced together, no light was perceived without another friction. When by the operation juſt now mentioned they had acquired the negative electricity, if they were placed, not upon the ſmooth body on which they had been rubbed, but on a rough conducting ſubſtance, they would, on their ſeparation, ſhow contrary electricities, which would again diſappear on their being joined together. If they had been made to repel each other, and were afterwards forced together, and placed on the rough ſurface above mentioned, they would in a few minutes be mutually attracted; the lowermoſt being poſitively and the uppermoſt negatively electrified.

If the two white ribbons received their friction upon the rough ſurface, they always acquired contrary electricities. The upper one was negatively, and the lower one poſitively electrified, in whatever manner they were taken off. The ſame change was inſtantaneouſly produced by any pointed conductor. If two ribbons, for inſtance, were made to repel, and the point of a needle drawn oppoſite to one of them along its whole length, they would immediately ruſh together.

The ſame means which produced a change of electricity in a ribbon already electrified, would communicate electricity to one which had not as yet received it; viz. laying the unelectrified ribbon upon a rough ſurface, and putting the other upon it; or by holding it parallel to an electrified ribbon, and preſenting a
pointed

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* *Phil. Tranſ.* vol. li. part i. 340.

General Phenomena.

pointed conductor to it. He placed a ribbon that was not quite dry under another that was well dried at the fire, upon a ſmooth plain; and when he had given them the uſual friction with his ruler, he found, that in what manner ſoever they were removed from the plain, the upper one was negatively and the lower one poſitively electrified.—If both ribbons were black, all theſe experiments ſucceeded in the ſame manner as with the white. If, inſtead of the ivory ruler, he made uſe of any ſkin, or a piece of ſmooth glaſs, the event was the ſame; but if he made uſe of a ſtick of ſulphur, the electricities were in all caſes the reverſe of what they had been before the ribbons were rubbed, having always acquired the poſitive electricity. When he rubbed them with paper either gilt or not gilt, the reſults were uncertain. When the ribbons were wrapped in paper gilt or not gilt, and the friction was made upon the paper laid on the plain above mentioned, the ribbons acquired both of them the negative electricity. If the ribbons were one black and the other white, whichever of them was laid uppermoſt, and in whatever manner the friction was made, the black generally acquired the negative and the white the poſitive electricity.

He alſo obſerved, that when the texture of the upper piece of ſilk was looſe, yielding, and retiform like that of a ſtocking, ſo that it could move and be rubbed againſt the lower one, and the rubber was of ſuch a nature as could communicate but little electricity to glaſs, the electricity which the upper piece of ſilk acquired did not depend upon the rubber, but upon the body on which it was laid. In this caſe, the black was always negative and the white poſitive. But when the ſilk was hard, rigid, and of a cloſe texture, and the rubber of ſuch a nature as would have imparted a great degree of electricity to glaſs, the electricity of the upper piece depended on the rubber. Thus, a white ſilk ſtocking rubbed with gilt paper upon glaſs became negatively, and the glaſs poſitively, electrified. But if a piece of ſilk of a firmer texture was laid upon a plate of glaſs, it was *always* electrified poſitively, and the glaſs negatively, if it was rubbed with ſulphur, and for the moſt part if it was rubbed with gilt paper.

If an electrified ribbon was brought near an inſulated plate of lead, it was attracted, but very feebly. On bringing the finger near the lead, a ſpark was obſerved between them, the ribbon was vigorouſly attracted, and both together ſhowed no ſigns of electricity. On the ſeparation of the ribbon, they were again electrified, and a ſpark was perceived between the plate and the finger.

When a number of ribbons of the ſame colour were laid upon a ſmooth conducting ſubſtance, and the ruler was drawn over them, he found, that when they were taken up ſingly, each of them gave ſparks at the place where it was ſeparated from the other, as did alſo the laſt one with the conductor; and all of them were negatively electrified. If they were all taken from the plate together, they cohered in one maſs, which was negatively electrified on both ſides. If they were laid upon the rough conductor, and then ſeparated ſingly, beginning with the lowermoſt, ſparks appeared as before, but all the ribbons were electrified poſitively, except the uppermoſt.—If they received the friction upon the rough conductor, and were all taken up at once, all the intermediate ribbons acquired the electricity, either of the higheſt or loweſt, according as the ſeparation was begun with the higheſt or the loweſt. If two ribbons were ſeparated from the bundle at the ſame time, they clung together, and in that ſtate ſhowed no ſign of electricity, as one of them alone would have done. When they were ſeparated, the outermoſt one had acquired an electricity oppoſite to that of the bundle, but much weaker.

A number of ribbons were placed upon a plate of metal to which electricity was communicated by means of a glaſs globe, and a pointed conductor held to the other ſide of the ribbons. The conſequence was, that all of them became poſſeſſed of the electricity oppoſite to that of the plate, or of the ſame, according as they were taken off; except the moſt remote, which always kept an electricity oppoſite to that of the plate *.

Chap. III. *Of the Phenomena produced by excited Paper.*

19
Experiments on paper.

1. When a ſingle leaf of writing paper, after being warmed, is laid on a table, and rubbed briſkly with a piece of caoutchouc, (elaſtic gum or India rubber) it becomes ſtrongly electrical; on attempting to remove it from the table, it is found to adhere as if it were beſmeared with ſome gluey ſubſtance; and if, before it is quite ſeparated, it be ſuffered to return to the table, it will fly back with conſiderable force, and will adhere almoſt as ſtrongly as at firſt.

2. On ſeparating it from the table immediately after rubbing, it will be ſtrongly attracted by the table or any ſubſtance preſented to it, and remain in contact for a conſiderable time.

3. When the knuckle is preſented to the paper on its being firſt taken from the table, a ſnapping noiſe is heard, which is more perceptible if the knuckle be made to paſs ſucceſſively over different parts of the paper. If this experiment is made in the dark, ſparks will be ſeen to accompany the ſnapping noiſe.

4. On employing a double piece, or two pieces of paper, theſe appearances will be increaſed. On attempting to ſeparate the two pieces of paper, they are found to adhere ſtrongly together, and their ſeparation is accompanied with a crackling noiſe, ſimilar to that produced by the application of the knuckle but not ſo loud. When quite ſeparated, on being brought again within ſome inches of each other they are ſtrongly and mutually attracted, and if, while ſeparated, one of them be held between the other and ſome contiguous ſubſtance, it will be alternately attracted by that ſubſtance, and the other piece, according as it is nearer the one or the other.

5. Placing a piece of clean new flannel between the paper and the table, or between the folds of the paper, does not appear to diminiſh the electrical appearances produced; but rubbing the paper with flannel produces no remarkable ſigns of electricity.

6. It is not neceſſary that the paper be rubbed on a table to produce theſe appearances; a book will anſwer as well, but with this difference, that if the book be in boards, the paper will produce no crackling when the knuckle is applied to it; but when the paper is double,

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* *Mem of the Acad. of Turin*, for 1763.

the ſeparation of the folds will be attended with the ſame crackling as before; whereas when the book is bound in leather, a ſingle ſheet when rubbed will produce the crackling on the application of the knuckle, while the double piece will produce it only when its folds are ſeparated. The adheſion of the paper to the books is in both caſes much ſlighter than its adheſion to the table, and in the caſe of the book in boards it is ſcarcely perceptible.

7. White paper of all kinds ſeems capable of producing theſe appearances, when rubbed with caoutchouc; but blotting paper whether white or red produces them in a very inferior degree, probably on account of the weakneſs of its texture not allowing it to be rubbed with ſufficient force.

In general, the ſtouter the texture of the paper, the ſtronger will be the ſparks and the attraction.

8. Paper does not appear to retain its electricity for any great length of time; in general, it ceaſes to ſhow any remarkable ſigns of electric power about 10 or 15 minutes after being excited.

9. Other ſubſtances beſides caoutchauc may be employed as rubbers for the excitation of paper, eſpecially the dry hand, but none ſucceed ſo well as caoutchouc.

The electric property of paper was firſt diſcovered by Mr Grey. The paper employed by him was the kind called white *preſſing paper*, which is of the ſame nature with card paper. Not only did this paper, when made as hot as his fingers could bear, produce a light when drawn briſkly through his fingers; but when his fingers were held near it, a light iſſued from them alſo, attended with a crackling noiſe *.

CHAP. IV. *Phenomena produced by the Tourmalin.*

20 Tourmalin the *lyncurium* of the ancients.

THE electrical power of this ſtone, ſo far at leaſt as reſpects its attraction of light hodies, was known to the ancients; as Theophraſtus ſpeaks of a ſtone by him called *lyncurium*, which agrees in all reſpects with the tourmalin, and which he ſays attracted ſtraws, aſhes, and even ſmall cuttings of iron and copper.

21 Experiments by Æpinus;

Nothing more ſeems to have been known of this ſtone till the year 1756, when M. Æpinus made a ſet of experiments on this ſtone, which were printed in the Hiſtory of the Academy of Sciences and Belles Lettres of Berlin for that year.

22 by the duc de Noya;

In 1758, the duc de Noya, in conjunction with M. Daubenton and Adamſon made ſome experiments on the tourmalin, but they do not ſeem to have been ſo accurate as thoſe of M. Æpinus.

23 Mr Canton.

Soon after this ſtone was introduced to the notice of the Engliſh, by Dr Heberden, who procured from Holland ſeveral, with which Æpinus's experiments were repeated by Meſſrs Wilſon and Canton.

24 Dr Prieſtley.

But the moſt complete ſeries of experiments on the tourmalin were made by Dr Prieſtley, and of theſe we ſhall here give a detailed account, as they compriſe nearly all that is known on the ſubject.

1. To aſcertain the kind of electricity produced, he had always at hand a ſtand of baked wood with four arms projecting from it. Three of theſe were of glaſs, having threads of fine ſilk as it comes from the worm faſtened to them, and at the end of each thread a ſmall piece of down. From the other arm hung a fine thread about 9 or 10 inches long, while a braſs arm ſuſpended a pair of pith-balls. At the other extremity of this arm, which was pointed, a jar could be placed, to receive the electricity, and by the repulſive power of it keep the balls equally diverging with poſitive or negative electricity; or ſometimes he ſuſpended the balls in an uninſulated ſtate within the influence of large charged jars: and laſtly, he had always a fine thread of trial at hand, by which he could diſcover whether the ſtone was electrical or not before he began his experiments (E).

2. Before he began any experiments on the ſtone, alſo, he never failed to try how long the fine threads, which he uſed as electrometers, would retain their virtue; and found this to be various in various caſes. When the threads would retain their electric virtue for a few minutes, he preferred them; but when this was not the caſe, he had recourſe to the feathers, which never failed to retain it for ſeveral hours. They might be touched without any ſenſible loſs of power, though they received their virtue very ſlowly. In the experiments now to be related, he made uſe of Dr Heberden's large tourmalin, whoſe convex ſide became poſitive and the flat ſide negative in cooling; and in all of them, when the poſitive or negative ſide of the tourmalin is mentioned, it is to be underſtood that which is poſitive or negative in cooling.

3. From Mr Wilcke's experiments on the production of ſpontaneous electricity, by melting one ſubſtance within another, he firſt conjectured that the tourmalin might collect its electricity from the neighbouring air: To determine which the following experiment was made. Part of a pane of glaſs was laid on the ſtandard bar of an excellent pyrometer, and upon that glaſs the tourmalin was placed. This bar was heated by a ſpirit lamp, ſo that the increaſe or decreaſe of heat in the tourmalin could thus be exactly determined. In this ſituation he obſerved, that whenever he examined the tourmalin, the glaſs had acquired an electricity contrary to that ſide of the ſtone which lay upon it, and equally ſtrong with it. If, for example, the flat ſide of the ſtone had been preſented to a feather electrified poſitively, as the heat was increaſing, it would repel it at the diſtance of about two inches, and the glaſs would attract it at the ſame or a greater diſtance; and when the heat was decreaſing, the ſtone would attract, and the glaſs repel it at the diſtance of four or five inches. The caſe was the ſame whichever of the ſides was preſented, as well as when a ſhilling was faſtened with ſealing-wax upon the glaſs; the electricity both of the ſhilling and glaſs being always oppoſite to that of the ſtone. When it came to the turn, the electricity was very quickly reverſed; ſo that

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* Phil. Tranſ. Abr. viii. 9.

(E) Dr Prieſtley's method will be better underſtood, after the reader has peruſed Chap. I. III. and XIII. of Part III.

General Phenomena.

that in leſs than a minute the electricity would be contrary to what it was before. In ſome caſes, however, viz. where the convex ſurface of the tourmalin was laid upon the glaſs or ſhilling, both of theſe became poſitive as well as the ſtone. This he ſuppoſed to be owing to the ſtone touching the ſurface on which it lay only in a few points, and that its electricity was collected from the air; which ſuppoſition was verified: for, getting a mould of Paris plaſter made for the tourmalin, and heating it in the mould, faſtened to a ſlip of glaſs, he always found the mould and glaſs poſſeſſed of an electricity contrary to that of the ſtone, and equally ſtrong with it. During the time of cooling, the mould ſeemed to be ſometimes more ſtrongly negative than the ſtone was poſitive; for once, when the ſtone repelled the thread at the diſtance of three inches, the mould attracted it at the diſtance of near ſix.

4. On ſubſtituting another tourmalin inſtead of the piece of glaſs; it was obſerved, that when one of the tourmalins was heated, both of them were electrified as much as the tourmalin and glaſs had been. If the negative ſide of a hot tourmalin was laid upon the negative ſide of a cold one, the latter became poſitive, as would have been the caſe with a piece of glaſs. On heating both the tourmalins, though faſtened together by cement, they acquired the ſame power that they would have done in the open air.

5. As the tourmalins could not in this caſe touch in a ſufficient number of points, it was now thought proper to vary the experiment by cooling the tourmalin in contact with ſealing-wax, which would fit it with the utmoſt exactneſs. On turning the ſtone, when cold, out of its waxen cell, it was found poſitive, and the wax negative; the electricity of the ſtone being thus contrary to what would have happened in the open air. The other ſide, which was not in contact with the wax, acquired the ſame electricity that it would have done though the ſtone had been heated in the open air; ſo that both ſides now became poſitive. In like manner the poſitive ſide of the ſtone, on being cooled in wax, became negative.

6. On attempting to aſcertain the ſtate of the different ſides of the tourmalin during the time it was heating in wax, many difficulties occurred. It was found impoſſible in theſe caſes to know exactly when the ſtone begins to cool; beſides, that in this method of treatment it muſt neceſſarily be ſome time in the open air before it can be preſented to the electrometer; and the electricity of the ſides in heating is by no means ſo remarkable as in cooling. In the experiments made with the tourmalin, when its poſitive ſide was buried in wax, it was generally found negative, though once or twice it ſeemed to be poſitive. On cooling it in quickſilver contained in a china cup, it always came out poſitive, and left the quickſilver negative; but this effect could not be concluded to be the conſequence of applying the one to the other, becauſe it is almoſt impoſſible to touch quickſilver without ſome degree of friction, which never fails to make both ſides ſtrongly poſitive though it be quite cold, and eſpecially if the ſtone be dipped deep into it. At laſt, ſuppoſing that the ſtone would not be apt to receive any friction by ſimple preſſure againſt the palm of the hand, he was induced to make the experiment, and found it fully to anſwer his expectations; for thus, each ſide of the ſtone was affected in a manner directly contrary to what would have happened in the open air.

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7. Faſtening the convex ſide of the large tourmalin to the end of a ſtick of ſealing-wax, and preſſing it againſt the palm of the hand, it acquired a ſtrong negative electricity, contrary to what would have happened in the open air. Thus it continued till it had acquired all the power it could receive by means of the heat of the hand; after which it began to decreaſe, though it continued ſenſibly negative to the very laſt. On allowing the ſtone to cool in the open air, its negative power conſtantly increaſed till it became quite cold.

8. On heating the ſame flat ſide by means of a hot poker held near it, and then juſt touching it with the palm of the hand when ſo hot that it could not be borne for any length of time, it became poſitive. Letting it cool in the air it became negative, and on touching it again with the hand it became poſitive; and thus it might be made alternately poſitive and negative for a conſiderable time. At laſt, when it became ſo cool that the hand could bear it, it acquired a ſtrong poſitive electricity, which continued till it came to the ſame degree of heat.

9. The wax was removed from the convex, and faſtened to the flat ſide of the ſtone; in which circumſtances it became weakly poſitive after receiving all the heat the hand could give it. On letting it cool in the open air it grew more ſtrongly poſitive, and continued ſo till it was quite cold; and thus the ſame ſide became poſitive both with heating and cooling.

10. On heating the convex ſide by means of a poker, and preſſing it againſt the palm of the hand as ſoon as it could be borne, it became pretty ſtrongly negative; though it is extremely difficult to procure any appearance of negative electricity from this ſide; and care muſt be taken that a ſlight attraction of the electrified feather, by a body not electrified, be not miſtaken for negative electricity.

11. On covering the tourmalin when hot with oil and tallow, no new appearances were produced; nor did the heating of it in boiling oil produce any other effect than leſſening the electricity a little; and the event was the ſame when the tourmalin was covered with cement made of bees-wax and turpentine. On making a ſmall tourmalin very hot, and dropping melted ſealing-wax upon it, ſo as to cover it all over to the thickneſs of a crown piece, it was found to act through this coating nearly, if not quite, as well as if it had been expoſed to the open air. Thus a pretty deception may be made: for if a tourmalin be incloſed in a ſtick of wax, the latter will ſeem to have acquired the properties of the ſtone.

12. On letting the ſtone cool in the vacuum of an air-pump, its virtue ſeemed to be diminiſhed about one half, owing no doubt to the vacuum not being ſufficiently perfect.

13. On fixing a thin piece of glaſs oppoſite and parallel to the flat ſide of the tourmalin, and about a quarter of an inch diſtance from it, in an exhauſted receiver, the glaſs was ſo ſlightly electrified, that it could not be diſtinguiſhed whether it was poſitive or negative.

13. On laying the ſtone upon the ſtandard bar of the

the pyrometer, and communicating the heat to it by means of a ſpirit lamp, it was extremely difficult to determine the nature of the electricity while the heat was increaſing to 70°; during which time the index of the pyrometer moved about one 7200th part of an inch. But if the ſtone was taken off the bar, and an electrified thread or feather preſented to that ſide which had lain next it, the convex ſide was always negative, and the flat one poſitive.

14. To determine what would be the effect of keeping the tourmalin in the very ſame degree of heat for a conſiderable time together, it was laid upon the middle of the bar, to which heat was communicated by two ſpirit lamps, one at each extremity; and making the index move 45 degrees, it was kept in the ſame degree for half an hour without the leaſt ſenſible variation; and it was obſerved, that the upper ſide, which happened to be the convex one, was always electrified in a ſmall degree, attracting a fine thread at the diſtance of about a quarter of an inch. If in that time it was taken off the bar, though ever ſo quick, and an electrified feather preſented to it, the flat ſide, which lay upon the bar, was negative, and the upper ſide very ſlightly poſitive, which appeared only by its not attracting the feather. On putting a piece of glaſs between the ſtone and ſtandard bar, keeping it likewiſe in the ſame degree of heat, and for the ſame ſpace of time as before, the reſult was the ſame; the glaſs was ſlightly electrified, and of a kind oppoſite to that of the ſtone itſelf. To avoid the inconvenience of making one ſide of the ſtone hotter than another, which neceſſarily took place when it was heated on the pyrometer, the following method was uſed. By means of two rough places which happened to be in the ſtone, it was tied with a ſilk thread which touched only the extreme edge of it; and thus being perfectly inſulated, it might be held at any diſtance from a candle, and heated to what degree was thought neceſſary; while, by twiſting the ſtring, it was made to preſent its ſides alternately, and thus the heat was rendered very equal in both. After being made in this manner ſo hot that the hand could ſcarce bear it, it was kept in that ſituation for a quarter of an hour. Then, with a bundle of fine thread held for ſome time before in the ſame heat, the electricity which it had acquired by heating was taken off, and it was found to acquire very little, if any; whence appeared the juſtneſs of an obſervation of Mr Canton's, that it is the change of heat, and not the degree of it, that produces the electric property of this ſtone.

15. On heating the ſtone ſuddenly, it may ſometimes be handled and preſſed with the fingers ſeveral times before any change takes place in the electricity which it acquires by heating, though it begins to cool the moment it is removed from the fire. In this caſe, however, the ſtone muſt be heated only to a ſmall degree. When the heat is three or four times as great as is ſufficient to change the electricity of the two ſides, the virtue of the ſtone is the ſtrongeſt, and appears to be ſo when it is tried in the very neighbourhood of the fire. In the very centre of the fire the ſtone never fails to cover itſelf with aſhes attracted to it from every quarter; whence it acquired its name in Dutch.

16. The tourmalin often changes its electricity very ſlowly; and that which it acquires in cooling never fails to remain many hours upon it with very little diminution. It is even poſſible, that in ſome caſes the electricity acquired by heating may be ſo ſtrong as to overpower that which is acquired by boiling; ſo that both ſides may ſhow the ſame power in the whole operation. "I am very certain (ſays the Doctor), that in my hands both the ſides of Dr Heberden's large tourmalin have frequently been poſitive for ſeveral hours together, without any appearance of either of them having been negative at all. At this time I generally heated the tourmalin, by preſenting each ſide alternately to a red hot poker, or a piece of hot glaſs, held at the diſtance of about half an inch, and ſometimes I held it in the focus of a burning mirror; but I have ſince found the ſame appearance when I heated it in the middle of an iron hoop made red hot. The ſtone in all theſe caſes was faſtened by its edge to a ſtick of ſealing-wax. This appearance I have obſerved to happen the ofteneſt when the iron hoop has been exceedingly hot, ſo that the outſide of the ſtone muſt have been heated ſome time before the inſide; and alſo I think there is the greateſt chance of producing this appearance, when the convex ſide of the ſtone is made the hotter of the two. When I heat the large tourmalin in this manner, I ſeldom fail to make both ſides of the ſtone poſitive till it be about blood-warm. I then generally obſerve a ragged part of the flat ſide towards one end of the ſtone become negative firſt, and by degrees the reſt of the flat ſide; but very often one part of the flat ſide will, in this method of treatment, be ſtrongly poſitive half an hour after the other part is become negative *.

Chap. V. *Phenomena produced by excited ſulphur.*

25
Experiments on ſulphur by M. Wilcke.

Sulphur is one of thoſe electrics which may be made to exhibit electrical appearances by being melted and ſuffered to cool again. Dr Gilbert had ſhown that ſulphur might be rendered electric by friction; but the firſt perſon who demonſtrated its excitability by melting, was Mr Wilcke, of Roſtoch in Lower Saxony, who firſt called this *ſpontaneous electricity*.

He melted ſome crude ſulphur in an earthen veſſel, and left it to cool after placing the veſſel on a conducting ſubſtance. On taking out the ſulphur when cool, he found it ſtrongly electrical, but this was not the caſe when the veſſel was placed on an electric.

He then melted ſulphur in glaſs veſſels, and found that both the glaſs and the ſulphur became electrical, but the former acquired a poſitive, and the latter a negative electricity. When glaſs veſſels were employed, it did not matter whether they were placed on electrics or conductors, except that the electricity produced, was ſtronger in the former caſe, and ſtill ſtronger when the glaſs was coated with ſome metallic ſubſtance. The electricity of the ſulphur was not produced till it began to contract, and was the ſtrongeſt when the greateſt degree of contraction had taken place. The electricity of the glaſs was always weakeſt when that of the ſulphur was ſtrongeſt, and the former was the ſtrongeſt poſſible when the ſulphur was ſhaken out before it had begun to contract.

He found that when melted ſulphur was poured into veſſels of rough glaſs, or into hollowed cakes of ſulphur, no electricity was produced.

Mr Wilcke alſo made experiments of the ſame kind with melted ſealing-wax, and found that when this

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* *Prieſtley, Hiſt. Elect.* part viii. ſect. 12.

was left to cool in veſſels of ſmooth glaſs or of wood, the ſealing-wax acquired a negative, and the glaſs or wood a poſitive electricity; but when it was cooled in cups of ſulphur, the ſealing-wax became electrified poſitively, and the ſulphur negatively †.

26 Æpinus's experiments.

Æpinus made ſome experiments on melted ſulphur which he cooled in metal cups. On examining them after the ſulphur was cold, he found that while the ſulphur remained in the cups, neither of them ſhowed any ſigns of electricity; but the moment they were ſeparated, both appeared ſtrongly electrical. The marks of electricity diſappeared however on replacing the ſulphur in the cups, and returned on their being again ſeparated. When ſeparated, the ſulphur was electrified poſitively, and the cups negatively; but if, before replacing the ſulphur in the cups, the electricity of either was taken off, the ſulphur and cups when together, would ſhow ſigns of that electricity that had not been taken off ‡.

It muſt be remarked here that though the electricity of the ſulphur, ſealing-wax, &c. in the above experiments appears to be the conſequence of their cooling after being melted, it is in fact excited by a degree of friction which theſe ſubſtances undergo by their contraction while cooling in the cups, or by being touched with the hand in making the experiment; for it is found that if they are cooled under circumſtances that prevent all friction, a very ſmall degree of which is ſufficient to excite theſe bodies, no electricity is produced. This appears from experiments made by M. M. Van Marum and Van Trooſtwryck, for the purpoſe of aſcertaining this point, an account of which is contained in the 33d volume of Rozier's Journal, to which we muſt refer our readers.

27 Durability of the electric power in ſulphur.

The durability of the electric power in excited ſulphur is ſo remarkable, that Mr Grey, from ſome experiments which he made on this and ſimilar ſubſtances, was led to ſuppoſe it perpetual. In particular, he poured melted ſulphur into a conical drinking glaſs, and when it was cold he found, that on taking off the glaſs the ſulphur never failed to attract light bodies, and that in every ſtate of the atmoſphere; and in fair weather the glaſs would alſo attract.

Mr Henly, who repeated Mr Grey's experiments, ſays, he has never known the ſulphur fail of ſhowing ſigns of electricity on the removal of the glaſs.

Although it be true that ſulphur, as well as roſin, ſealing-wax, amber, and ſilk, retain the electric power for a conſiderable time, this is, however, continually diminiſhing, and at length diſappears altogether.

28 Electricity of chocolate.

Other ſubſtances, as well as ſulphur and ſealing-wax, become electrical by cooling after being melted. Mr Henly obſerved that chocolate, when firſt from the mill, as it cools in the tin pans into which it is received, becomes ſtrongly electrical, and retains this property for ſome time after being taken out of the pans, but loſes it by handling. If melted again, and left to cool as before, its electricity returns, though in a leſs degree; and thus it may be renewed once or twice, but ſtill in a much ſmaller degree than before. But if before pouring it into the pan, it be well mixed with a little olive oil, it becomes again ſtrongly electrical.

29 Sealing-wax excited by being broken.

When a ſtick of ſealing-wax is broken acroſs, each piece becomes electrified at the extremities that were contiguous, the one poſitively and the other negatively.

30 Electricity of wood ſhavings.

When wood that is hard and pretty dry, is cut or ſhaved, the ſhavings are rendered electrical. This fact was firſt obſerved by Mr William Wilſon, who, from a number of experiments, draws the following concluſions.

From theſe experiments it appears, that when very dry wood is ſcraped with a piece of window glaſs, the ſhavings are always poſitively electrified. And if chipped with a knife, the chips are poſitively electrified if the wood is hot, the edge of the knife not very ſharp, and negatively electrified if the wood is quite cold. But if the edge of the knife is very keen, the chips will be negatively electrified whether the wood is hot or cold.

The greateſt number of trials was made with the inſulated knife, which was always electrified contrarily to the chips; but the ſurface of the wood where the chips were cut from was very ſeldom electrified, and when it was it, was always but weakly ſo, and of the ſame denomination as that of the weakeſt of the other two. Mr Wilſon repeatedly found that if a piece of dry and warm wood is ſuddenly ſplit aſunder, the two ſurfaces which were contiguous are electrified, one ſide poſitive and the other negative.

31 Electricity of powders.

Powders, either of electrics or conductors, are rendered electrical by dropping them on an inſulated metallic plate.

The method, as deſcribed by Mr Cavallo, is as follows:

" Inſulate a metal plate upon an electric ſtand, ſuch as a wine glaſs, and connect with it a cork-ball electrometer; then the powder required to be tried, being held in a ſpoon, or other thing, at about ſix inches above the plate, is to be let fall gradually upon it. In this manner the electricity acquired by the powder, being communicated to the metal plate, and to the electrometer, is rendered manifeſt by the divergence of the threads; and its quality may be aſcertained in the uſual manner; to be hereafter deſcribed.

" It muſt be obſerved, that if the powder is of a conducting nature, like the amalgam of metals, ſand, &c. it muſt be held in ſome electric ſubſtance, as a glaſs phial, a plate of ſealing-wax, or the like. Sometimes the ſpoon that holds the powder may be inſulated, in which caſe, after the experiment, the ſpoon will be found poſſeſſed of an electricity contrary to that of the powder.

" In performing theſe experiments, care muſt be taken to render the powders, and whatever they are held in, as free from moiſture as poſſible; ſometimes it being neceſſary to make them very warm, otherwiſe the experiment is apt to fail. The following are the particulars which have been obſerved with this method, which, however, are neither numerous, nor often repeated; but they may ſuffice to excite the curioſity of thoſe perſons, who have leiſure and the opportunity of repeating them more at large and in a greater variety.

" Powder of roſin, whether it be let fall from paper, glaſs, or a metal ſpoon, electrifies the plate ſtrongly negative; the ſpoon, if inſulated, remaining ſtrongly poſitive. Flower of ſulphur produces the ſame effect, but in a little leſs degree. Pounded glaſs, let fall from

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† *Wilcke Diſput.*

‡ *Æpini Tentamen.*

from a piece of paper, made dry and warm, electrifies the plate negatively, but not in ſo ſtrong a degree as roſin. If it be let fall from a braſs cup, it electrifies the plate poſitively, but in a very ſmall degree.

“ Steel-filings let fall either from a glaſs phial or paper, electrify the plate negatively; but braſs-filings, treated in the ſame manner, electrify the plate poſitively. The amalgam of tin-foil and mercury, gunpowder, or very fine emery, electrify the plate negatively, when they are let fall upon it from a glaſs phial. Quickſilver, from a glaſs phial, electrifies the plate poſitively.

“ Soot from the chimney, or the aſhes of common pit-coal mixed with ſmall cinders, electrify the plate negatively, when let fall from a piece of paper.”

32 Electricity ſhown by vapour. M. Volta diſcovered, that when water and ſome other fluids are reduced to a ſtate of vapour, by throwing the fluid on ſome lighted coals placed in an inſulated crucible, the vapour ſhews ſigns of poſitive electricity, while the coals it is leaving are negatively electrified; and hence it is concluded, that all fluids in the act of evaporation become electrical, the vapour being electrified poſitively, and the body which it is leaving negatively; and again, that when vapour becomes condenſed into a fluid, it becomes negatively electrified, leaving the bodies with which it was laſt in contact in a ſtate of negative electricity.

33 Galvanic electricity. Some conductors arranged in certain ways will produce electrical appearances without friction, or communication with any electric except the air.

Thus if a plate of zinc, a plate of ſilver, or of copper, and a piece of woollen cloth moiſtened with ſome ſaline ſolution, as of muriat of ammonia, be arranged in the order we have mentioned one above another, they will manifeſt ſigns of electricity, which will be the ſtronger in proportion as the ſets of metal and cloth are more numerous.

The ſame appearances will be more manifeſt if the metallic plates joined together be fixed in a trough at ſmall diſtances, while the intermediate ſpaces are filled with the ſaline ſolution.

As the appearances produced by conductors arranged in this way are of a peculiar nature, we ſhall not treat of them in this article, but refer the conſideration of them till we come to GALVANISM.

Under the ſame article will alſo be conſidered the electrical phenomena which are produced by certain animals, as the torpedo, &c.

The glaſs tube and the dry hand, mentioned in (1), conſtitute the moſt ſimple *electrical apparatus* of which the eſſential parts are the *electric* and the *rubber*. But for the purpoſe of experiment it is neceſſary to have the electric of conſiderable ſize, furniſhed with ſome proper ſubſtance which can always perform the office of a *rubber*, and ſo firmly fixed as not to be eaſily diſturbed from its ſituation in the courſe of our experiment. We ſhall then have what is called an *electrical machine*.

As much of the ſucceſs of electrical experiments depends on the proper conſtruction and management of the *machine* and its attendant apparatus, we ſhall here give a pretty full account of the uſual apparatus before we proceed in explaining the principles of the ſcience.

PART II.

OF ELECTRICAL APPARATUS.

CHAP. I. *Of the Conſtruction of Electrical Machines.*

34 Conſtruction of electrical machines. WE ſhall firſt lay down the general principles on which the conſtruction of an electrical machine and the adjuſting of its ſeveral parts depends; and ſhall afterwards deſcribe ſome of the more important machines which are now in uſe.

The principal parts in an electrical machine are the *electric*, the *engine* by which it is to be ſet in motion, the *rubber*, and the *prime conductor*.

35 Electric. Several ſubſtances have, at various times been employed as electrics, as *ſulphur* (F), *roſin*, *poliſhed glaſs*, and *rough glaſs*; and they have been uſed of various form as *globes*, *ſpheroids*, *cylinders*, &c. The reaſon of this variety of form ſeems to be that experience had not ſhown what form was the moſt convenient; but the different ſubſtances were employed for the purpoſe of producing a poſitive or negative electricity as the nature of the experiment or the fancy of the operator might require.

But as this purpoſe is better anſwered by inſulating the rubber, or allowing it to communicate freely with conductors, poliſhed glaſs is almoſt the only ſubſtance at preſent employed as the electric of a machine. Globes of glaſs are ſometimes uſed, but the moſt convenient forms are cylinders and plates.

36 Cylinder. The moſt convenient ſize for globes is from nine to twelve inches diameter. They are made with one neck, which is cemented to a ſtrong braſs cap, in order to adapt them to a proper frame. The moſt convenient cement for holding together the parts of electrical apparatus is made by melting together, over a gentle fire, two parts of roſin, two of bees-wax, and one of powdered red ochre. 37 Cement for electrical apparatus. This cement is much better than roſin alone, as it ſerves the purpoſes of inſulation equally well, and is much leſs brittle. Globes were formerly

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(F) The firſt perſon who conſtructed any thing like an electrical machine was Otto Guericke, burgomaſter of Magdebourg, who lived in the latter end of the 17th century. He formed a globe of ſulphur by melting this ſubſtance in a glaſs globe, which he then broke away from it, little imagining that the glaſs itſelf would have anſwered his purpoſe much better. *Vid. Experimenta Magdeburgica.*

formerly much more uſed than at preſent; their great advantage appears to be, that by making the electric revolve on an axis nearly perpendicular, the upper part is more completely inſulated; but one great diſadvantage attends this motion, namely, that as the preſſure is applied at a diſtance from the fulcrum, it in time looſens the adheſion of the ſtrongeſt cement.

38
Plates of glaſs.

Plates of glaſs are much in faſhion on the continent; and they ſeem to attribute to this form much of the wonderful power of their machines, as of that at Haarlem, to be hereafter mentioned. Perhaps the greateſt advantage of plates is that the friction may be applied to both ſurfaces at once; but it may be doubted, whether this be not an imaginary advantage, and this form is attended with ſeveral material inconveniences; as, 1ſt, Plates cannot bear any great preſſure of the rubber; 2d, They cannot be inſulated without very complicated machinery; 3d, As they are fixed by the centre, and the friction is applied towards the circumference, if much force be employed, there will be great danger of breaking the plate, or at leaſt of looſening it, and thus diſturbing the equability of its motions; and, 4thly, They are much more expenſive than any other form, and hence, as they are much expoſed to injury, the replacing of them becomes a very ſerious object.

The ingenious Mr Cuthbertſon has contrived to obviate ſome of theſe diſadvantages, and his plate machines are very conveniently managed, as well as very powerful in their effect.

39
Cylinders to be preferred.

On the whole, the cylindrical form ſeems preferable to any other, and this is now almoſt univerſally employed. The cylinders ſhould be blown as light as poſſible, conſiſtently with ſufficient ſtrength, and their ſurface ſhould be as equable and free from knots or protuberances as may be; for theſe not only render the cylinder more liable to be broken, but prevent the ſilk of the rubber from being cloſely applied to every part of the ſurface. To avoid theſe inequalities, the cylinder ſhould be blown at the time when the glaſs is in the moſt complete ſtate of fuſion, and this is found to be the caſe, when the pot is about half emptied, which happens at the London glaſs-houſes on Wedneſdays and Thurſdays.

The cylinders are uſually made of the beſt flint-glaſs, but it is not determined which is the beſt kind. In ſize they vary from eight inches long and four in diameter to two feet long and one foot in diameter, which is perhaps as large as they can be conveniently blown. Very ſmall cylinders are, however, of little uſe, and it may be doubted whether the diameter ſhould not be greater in proportion to their length than what is above aſſigned. It is of great conſequence that the cylinders ſhould have been properly annealed, or that they ſhould be brought very gradually from the temperature of the glaſs-houſe to that of the external air; as when they have been too ſuddenly cooled, they are apt to fly in pieces in the act of whirling, to the great annoyance both of the experimenter and the ſpectators.

Cylinders are made with two necks; and the openings of theſe ſhould be ſo wide as to admit the hand to clean the inner ſurface of the glaſs, which is ſometimes ſullied by condenſed vapour. Theſe necks are cemented as above directed, to caps of braſs, which are much ſuperior to wooden caps, as they may be made much more ſmooth and equal.

Braſs caps have been objected to on account of the conducting power of the metal; but this objection is abſurd, as the inſulation depends on the diſtance between the cap and the cuſhion, which, as will be mentioned preſently, ſhould be as great as poſſible. Indeed wood, if ever ſo well dried, is but a very imperfect inſulator, and the hardeſt can never be ſo completely poliſhed as a metallic ſubſtance. The braſs cap ſhould be compoſed of two parts; one a ring to be cemented round the neck of the cylinder, with an aperture ſufficient to admit of the introduction of the hand within the glaſs, and with a ſurface as extenſive as poſſible, that the adheſion of the cement may be the more complete; the other a head or lid of braſs completely poliſhed, to be ſcrewed into the ring, and with an orifice into which the winch or the pin on which the other end of the cylinder is ſupported may be ſcrewed.

40
Coating of globes and cylinders.

It has been thought of advantage to line the inſide of the glaſs with ſome electric ſubſtance, as wax, roſin, &c.: this has been thought by ſome to increaſe the excitability of the glaſs. It ſeems aſcertained, however, that if ſuch a coating does not make a good cylinder better, it at leaſt often improves a bad one. The compoſition moſt approved for coating globes or cylinders is formed of four parts of Venice turpentine, one part of roſin, and one of bees-wax, melted together and kept boiling over a gentle fire for about two hours, frequently ſtirring it. When a veſſel is to be coated with this compoſition, a ſufficient quantity of it, broken into ſmall pieces, is to be put within the globe or cylinder, which is then held to the fire to melt the compoſition; and by conſtantly turning it round, the coating is to be ſpread equally over the ſurface to about the thickneſs of a ſixpence. In doing this, care muſt be taken to heat the glaſs very gradually and equally, otherwiſe it is liable to be broken during the operation.

41
Means of moving the electric.

The electric is ſet in motion either by a ſimple winch, or by means of multiplying wheels. The former, as being more ſimple, and conſequently leſs liable to produce diſorder in the motion of the machine, is generally to be preferred. The handle of the winch is ſometimes made of glaſs, but this is unneceſſary; for the glaſs does not ſhorten the interval, which is moſt favourable to the diſperſion of the electric power.

Multiplying wheels were much more common formerly than at preſent. The uſual method of employing theſe is, to fix a wheel on one ſide of the frame of the machine, which is turned by a winch, and has a groove round its circumference.

Upon the braſs cap of the neck of the glaſs globe, or one of the necks of the cylinder, is fixed a pulley, whoſe diameter is about the third or fourth part of the diameter of the wheel: then a ſtring or ſtrap is put over the wheel, and the pulley; and by theſe means, when the winch is turned, the globe or cylinder makes three or four revolutions for one revolution of the wheel. The principal inconvenience attending this conſtruction, is, that the ſtring is ſometimes ſo very ſlack, that the machine cannot work. To remedy this, the wheel ſhould be made moveable with reſpect to the electric, ſo that, by means of a ſcrew, it may be fixed at the proper diſtance; or elſe the pulley ſhould have

have ſeveral grooves of different radiuſes on its circumference.

The chief advantage of multiplying wheels, is that the arm of the operator is leſs fatigued by turning the machine, when theſe are employed, than when a ſimple winch is uſed; and as by theſe the motion of the electric is rendered quicker, it is ſuppoſed by ſome that its electric power is proportionally increaſed.

In ſome machines, inſtead of the pulley or ſtring deſcribed above, there are uſed a wheel and pinion, or a wheel and an endleſs ſcrew. This machinery requires conſiderable nicety in its conſtruction, is apt to produce an unpleaſant rattling, and unleſs frequently oiled, the conſtant friction of the parts againſt each other ſoon wears them away, ſo as to render the motion very unſteady.

42 Rubber.

The rubber (G), by which the electric is to be excited, conſiſts of two parts. One part is a cuſhion, which is uſually made of a piece of red baſil ſkin, ſtuffed with hair or flannel. The cuſhion is either fixed to a piece of wood well rounded at the edges, and faſtened to a ſupport of glaſs, or ſome other inſulating ſubſtance; or where two conductors are employed, it is fixed to one of theſe. The cuſhion ſhould be made as hard as the bottom of an ordinary hair-chair, and ſhould be ſo adapted to the ſurface of the cylinder, as to preſs equally on it in every part. For this purpoſe it is generally provided with a ſpring, by which means it may be the better adapted to any inequalities of the ſurface of the glaſs; in the uſual conſtruction of the cuſhion the ſpring is placed without, but Mr Jones, inſtrument-maker in London made, what he conſiders as a great improvement on the mode of placing it. This conſiſts in a ſpring placed within the rubber itſelf; the action of which is found to be better ſuited for adapting the rubber to the inequalities of the glaſs, than that placed entirely without the rubber. It conſiſts of a piece of flexible iron or braſs, repreſented edgewiſe by A, fig. 3.; and it is evident that it acts in a much more parallel and uniform manner than the former, which is conſtantly changing the preſſure of the line of contact betwixt the rubber and cylinder while it paſſes from the under to the upper ſide, thus rendering the effect inconſtant and uncertain.

The length of the cuſhion ſhould not exceed one-third of the length of the cylinder; for if it were longer, the inſulation would be much leſs complete, ſince one end of the conductor (when the rubber is fixed to a conductor) muſt always be nearer to the hand by two or three inches than the cuſhion.

The other part of the rubber conſiſts of a piece of black Perſian ſilk as broad as the length of the cuſhion, and reaching from it over nearly one half of the cylinder. It ſhould be ſewed upon a wire, bent at both ends, and theſe ends are adapted to holes made on the upper edge of the wood to which the cuſhion is faſtened; or it may be glued to the edge of the cuſhion: but the former mode of fixing it is to be preferred, as it can then be eaſily removed.

The rubber ſhould be inſulated in the moſt perfect manner; as, when inſulation is not required, it may be eaſily taken off by a chain or wire hung upon it, and thus communicate with the earth or with any unelectrified body; but where there is no contrivance for inſulating the rubber, it is impoſſible to perform many of the moſt curious experiments. In ſhort, to conſtruct the rubber properly, it muſt be made in ſuch a manner, that the ſide it touches in whirling may be as perfect a conductor as it can be made, in order to ſupply electricity as quick as poſſible; and the oppoſite part ſhould be as perfect a non-conductor as poſſible, in order that none of the electric power accumulated upon the glaſs may return back to the rubber; which has been found to be the caſe when the rubber was not made in a proper manner (H).

43 Wolff's improvement of the rubber.

Of late, a conſiderable improvement in the rubber has been made by M. Wolff, of Hanover. The conſtruction and advantage of his rubbers, as applied to a plate machine ſimilar to that of Van Marum, of which an account will be given by and by, is thus deſcribed by the author in a paper in Gilbert's *Annalen der Phyſick* for 1802, and tranſlated in Nicholſon's Journal, for February 1804, from which we have copied them.

The four rubbers are made of dry walnut wood ſoaked in amber varniſh, and are 5⅛ inches long, 1¼ broad, and a little more than one quarter of an inch thick. The metallic plate that communicates with the leather covered with amalgam, is only 1¼ inch broad, and is fixed externally to the centre of the piece of wood. The rubbers are preſſed towards the glaſs by means of a ſpring. They are covered with a piece of thick woollen, upon which is a piece of fine neat's leather. After the leather is faſtened to the wood, it is wetted, and preſſed between two boards, where it is kept till it is again dry. Thus it is rendered very flat, and its edge very ſharp, and all its parts will apply to the ſurface of the glaſs. This piece of leather is covered with another a little broader, the rough ſurface of which is towards the glaſs, and its lower edge on the ſide towards which the plate moves; and its lower edge on the other ſide from which the plate moves, being likewiſe very ſharp. The piece of ſilk is applied with accuracy to this leather. Before it is faſtened on, it is heated, and beſmeared firſt with butter of cacao, then with a large quantity of Kienmayer's amalgam (I); and after it is faſtened on, it is compreſſed in conjunction with the wood, or preſſed ſtrongly againſt the machine. The leather is next covered with amber varniſh, amalgam is ſpread over this, and after the varniſh is dry, it is ſmoothed with a burniſher. This is repeated ſeveral times. The whole being very dry, and the rubber being preſſed ſo as to touch the glaſs in all points,

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(G) For a long time the only rubber employed was the dry hand of the experimenter, till the middle of the 18th century, when M. Winckler, profeſſor at Leipſic, introduced the cuſhion. It was long after this, however, before electricians could be perſuaded that any rubber was better than the clean dry human hand. Vid. *Prieſtley's Hiſt.* part i. ſec. 7.

(H) The improvement of the ſilk flap was firſt introduced by Dr Nooth. Vide *Phil. Tranſ.* vol. lxiii.

(I) He adds to this amalgam as much ſilver, as the mercury can diſſolve in conjunction with the zinc.

Electrical Apparatus.

points, the leather coated with amalgam (K) is covered with a piece of fine white paper, as long as the leather, and half an inch broader, ſo as to cover the ſeam that faſtens the ſilk to the leather; and the paper is faſtened to the wood above or below, accordingly as it is on the aſcending or deſcending ſide of the plate.

Dry paper is known to be capable of acquiring a high ſtate of electricity, which induced me to try this ſubſtance as an immediate rubber. The following are the advantages, that by my experiments, repeated and varied in a great number of ways, I have found paper employed as a rubber to poſſeſs over every other known ſubſtance.

1. The glaſs is not rendered dull by the friction, as happens at length, and by frequent uſing, when it is in immediate contact with the amalgam.

2. By the immediate contact of the amalgam, the glaſs frequently contracts ſtreaks here and there, that occaſion a circulation of the fluid. This cannot take place in the conſtruction I propoſe.

3. Neither the glaſs nor the ſilk can be ſoiled. It it well known, that the cleanneſs of the glaſs, as well as of the rubber and the whole machine in general, is of importance in producing an intenſe degree of electricity. It is true, that it has been propoſed to apply the amalgam to the glaſs inſtead of the rubbers; but the greater effect, that ſeems to be produced by this laſt method, is only apparent, and conſiſts entirely in the circulation of the fluid on the glaſs, while far from exciting or accumulating more of the fluid, this proceſs and the circulation diſperſe it.

4. The amalgam on the leather does not require to be frequently renewed. The duſt of the amalgam, that is depoſited on the edges of the paper, is injurious only when accumulated there in ſufficient quantity to be conveyed to the glaſs, from which however it may eaſily be removed.

5. The return and paſſage of ſparks to the rubbers are rendered more difficult, as the paper ſufficiently covers the borders of the rubbers, that are turned toward the axis.

6. In my conſtruction the rubbers may be larger than in the uſual way, and in reality they are larger in proportion in my machine than in Van Marum's. No ſpark paſſes the axis, unleſs the air be very damp. I am perſuaded, that, by adopting my conſtruction, the rubbers of a plate of 32 inches, ſuch as Van Marum's is, may be eleven inches inſtead of nine, in which caſe there would ſtill be two inches for the diameter of the piece of wood that faſtens the plate to the axis, and three inches for the diſtance from this piece to the rubbers; which I think would be ſufficient in theſe circumſtances; and the friction being on a larger ſurface of the plate, the effect muſt naturally be much greater. I ſhall try this alteration of the rubbers on large plates of Bohemian glaſs, as well as on Engliſh cylinders of 18 inches diameter, and 21 inches long. The reſult I have already obtained with a ſmall cylinder gives me reaſon to hope much more complete ſucceſs with a large one.

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7. With my rubbers the friction may be rendered much greater, than with thoſe the amalgam of which is in immediate contact with the glaſs, and ſoils it; beſides, the plate turns with an uniform friction.

8. The activity of the machine is extraordinarily increaſed by this conſtruction. The greater freedom with which the plate moves, even under a greater preſſure, and the paper's preventing the glaſs from being ſoiled, would be ſufficient to produce this effect; even if the greater preſſure alone did not occaſion a more powerful effect than can be obtained from common machines.

44 Prime conductor.

The laſt part of a machine which we are to deſcribe is the *prime conductor*.

This is a cylindrical tube, uſually made of braſs, copper or tinned iron, the two firſt of which are much the beſt, as they admit of more nicety in the conſtruction, eſpecially of being better poliſhed. When required very large, the cylinder may be made of paſteboard covered with tin-foil or gold-leaf. It is of great conſequence that the conductor be made perfectly free from points or edges, and where holes are made in it, as is commonly done, for the purpoſe of experiment, theſe ſhould have their edges perfectly ſmooth and even. The cylinder is cloſed at both ends by ſpherical lids or covers, made ſo as to fit with the greateſt accuracy, but ſo as to be taken off, if requiſite. Theſe ends are ſometimes made larger than the reſt of the cylinder; but this is unneceſſary, and it is much better that they ſhould form with it one ſmooth and uniform ſurface. In ſome machines the conductor is placed at right angles to the glaſs cylinder, but it is now uſually placed parallel to it. At the end or ſide oppoſite the glaſs, are fixed a row of metallic points, for receiving the electric power; theſe are generally either fixed immoveably in the ſide or end of the conductor, or are fixed along a ſeparate piece of ſtrong braſs wire, which is made to ſhut into two holes in the conductor, ſo that the points can be removed at pleaſure. Mr Reid contrived to fix them to rings turning on an axis, the ends of which were forced into holes made in the conductor, ſo that the points reſted on the glaſs, with which they were thus in perpetual contact, without diſturbing its motion. It is certainly of great advantage to have the points as near the glaſs as poſſible, but this mode of fixing them is attended with the inconvenience of multiplying the protuberances on the ſurface of the conductor.

The ſize of the conductor is of ſome conſequence; in general its length ſhould equal that of the glaſs cylinder including its necks, and its diameter ſhould be about one-third of that of the cylinder. It ſhould be

inſulated

(K) The amalgam mentioned by M. Wolff is formed of two parts of *mercury*, one part of *purified zinc*, and one of *pewter*. The zinc and pewter are melted together, and, before the mixture is quite cool, the mercury is added. The whole is then poured into a cloſe box, ſhaken for ſome time and left to cool on a marble ſlab. When nearly cold, it is reduced to powder in a glaſs or earthen mortar, taking care not to triturate it ſo long as to make it turn gray. The Baron de Kienmayer, the author of this amalgam, has given a particular account of its preparation and uſes in the 33d vol. of Rozier's Journal. p. 96. *q. v.*

inſulated by being fixed on a pillar of glaſs covered with ſealing-wax. For this purpoſe, the ſealing-wax may be diſſolved in alcohol (ſpirit of wine), and thus applied to the glaſs pillar; but it is better to heat the glaſs gradually, and then rub it over with the ſealing-wax till it is covered to a ſufficient thickneſs. Where there are two conductors, one of them ſupports the rubber, and is called the *negative* conductor; this is not furniſhed with points: the other, which is what we have juſt deſcribed, is placed oppoſite and parallel, on the other ſide of the glaſs, and is called the *poſitive* conductor (L).

It is proper to have ſeveral braſs balls furniſhed with ſtalks, ſome ſtraight, and others curved, which may be fitted into the holes in the ſurface of the conductor.

The balls ſhould be of various ſizes, and ſhould be made to ſcrew upon the ends of the ſtalks, ſome of which ſhould be terminated by points. It is convenient alſo that ſome of the ſtalks be made with a joint, ſo that the ball or point can be placed in any poſition.

45 Other apparatus attached to the machine.

Electrical machines ſhould be furniſhed with one or more chains, by which, when inſulation is not required, either of the conductors may be made to communicate with the table or with the floor.

There is alſo attached to the electrical machine, a ſtool with four glaſs legs or feet, for the purpoſe of inſulating various bodies in the courſe of experiment, and hence called *the inſulating ſtool*. This ſtool ſhould be made either of baked wood or thick glaſs, and ſhould be ſufficiently large to ſupport an ordinary chair, or at leaſt ſo large that a perſon can eaſily ſtand on it.

CHAP. II. *Deſcription of ſome particular Electrical Machines.*

46 Dr Prieſtley's machine. Fig 4.

THE firſt machine which we ſhall deſcribe is one invented by Dr Prieſtley, which has been conſidered by ſome as ſo ingenious, that it has been called *a univerſal electrical machine*.

It is thus deſcribed by Dr Prieſtley in his hiſtory.

The frame conſiſts of two ſtrong boards of mahogany of the ſame length, parallel to one another, about four inches aſunder; and the lower is an inch on each ſide broader than the upper. In the upper board is a *groove*, reaching almoſt its whole length. One of the *pillars*, which are of baked wood, is immoveable, being let through the upper board, and firmly fixed in the lower, while the other pillar ſlides in the groove above mentioned, in order to receive globes or cylinders of different ſizes; but it is only wanted when an axis is uſed. Both the pillars are perforated with *holes* at equal diſtances, from the top to the bottom; by means of which globes may be mounted higher or lower according to their ſize; and they are tall to admit the uſe of two or more globes at a time, one above the other. Four of a moderate ſize may be uſed, if two be fixed on one axis; and the wheel has ſeveral grooves for that purpoſe.

If a globe with only one neck be uſed, a braſs arm with an open ſocket, is neceſſary to ſupport the axis beyond the pulley; and this part is alſo contrived to be put higher or lower, together with the braſs ſocket in which the axis turns. The axis is made to come quite through the pillar, that it may be turned by another handle, without the wheel, if the operator chuſes. The frame being ſcrewed to the table, may be placed nearer to, or farther from the wheel, as the length of the ſtring requires, in different ſtates of weather. The wheel is fixed in a frame by itſelf, by which it may have a ſituation with reſpect to the pulley, and be turned to one ſide, ſo as to prevent the ſtring from cutting itſelf. The hinder part of this frame is ſupported by a foot of its own.

The rubber conſiſts of a hollow piece of copper lined with horſe hair, and covered with a baſil ſkin. It is ſupported by a ſocket, which receives the cylindrical axis of a round and flat piece of baked wood, the oppoſite part of which is inſerted into the ſocket of a bent ſteel ſpring. Theſe parts are eaſily ſeparated; ſo that the rubber, or piece of wood that ſerves to inſulate it, may be changed at pleaſure. The ſpring admits of a twofold alteration of poſition. It may be either ſlipped along the groove or moved in a contrary direction; ſo as to give it every deſirable poſition with reſpect to the globe or cylinder; and it is beſides furniſhed with a *ſcrew*, which makes it preſs harder or lighter, as the operator chuſes.

The prime conductor is a hollow veſſel of poliſhed copper, in the form of a pear, ſupported by a pillar, and a firm baſis of baked wood, and it receives its fire by means of a *long arched wire, or rod of very ſoft braſs*, eaſily bent into any ſhape, and raiſed higher or lower, as the globe requires; and it is terminated by an *open ring*, in which are hung *ſome ſharp-pointed wires* playing lightly on the globe when it is in motion. The body of it is furniſhed with *holes* and *ſockets*, for the inſertion of metallic rods, to convey the fire wherever it is wanted, and for many other purpoſes convenient in a courſe of electrical experiments. The conductor is by this means ſteady, and yet may be eaſily put into any ſituation. It collects the fire perfectly well, and (what is of the greateſt conſequence though but little attended to) retains it equally everywhere.

When poſitive electrity is wanted, a wire or chain, as is repreſented in the figure, connects the rubber with the table, or the floor. When negative electricity is wanted, that wire is connected with another conductor, ſuch as is repreſented at fig. 5. while the conductor at fig. 4. is connected by another wire or chain with the table. If the rubber be made tolerably free from points, the negative power will be as ſtrong as the poſitive.

In ſhort, the capital advantages of this machine are, that glaſs veſſels, or any other electric body, of any ſize or form, may be uſed, with one neck or two necks

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(L) M. Boze, profeſſor at Wittemburg, firſt employed a *prime conductor*; his conductor was a tube of iron or tin, which he inſulated at firſt by its being held by a man ſtanding on cakes of roſin, and afterwards by ſuſpending it by ſilken lines, horizontally before the globe. For a long time a gun-barrel was employed as a prime conductor.

necks at pleaſure; and even ſeveral of them at the ſame time if required. All the eſſential parts of the machine, the *globe*, the *frame*, the *wheel*, the *rubber*, and *conductor*, are quite ſeparate; and the poſition of them to one another may be varied in every manner poſſible. The rubber has a complete inſulation, by which means the operator may command either the poſitive or negative power, and may change them in an inſtant. The conductor is ſteady and eaſily enlarged, by rods inſerted into the holes, with which it is furniſhed, or by the conjunction of other conductors in order to give larger ſparks, &c. The wheel may be uſed or not at pleaſure; ſo that the operator may either ſit or ſtand to his work, as he pleaſes; and he may with the utmoſt eaſe both manage the wheel and his apparatus.

Plate CLXXXVII

This machine is figured in Plate CLXXXVII. fig. 4. where

a a. Repreſent the two boards of the frame.
b, One of the pillars.
c, The braſs arm with the open ſocket.
d, The axis on which the globe turns.
e, The frame to which the wheel is fixed.
f, The rubber; *g*, The piece of baked wood; *h*, The ſteel ſpring; *i*, The ſcrew.
k, The prime conductor; *l*, The rod or wire; *m*, The points.
n, The wire for connecting the rubber with the table.

47
Machine by Dr Ingenhouſz.

Next to Dr Prieſtley's machine, we ſhall deſcribe one which was invented by Dr Ingenhouſz, in which a plate of glaſs is employed inſtead of a globe or cylinder.

There is a circular plate of glaſs, about a foot in diameter, perforated in the centre by an iron axis, upon which it is turned vertically by means of a winch. It has four cuſhions, each above two inches long, which are ſituated at the oppoſite ends of its vertical diameter. It moves in a frame compoſed of a bottom board about a foot ſquare, or a foot long and about ſix inches broad, upon which are raiſed two other ſmaller boards, parallel to each other, and faſtened together at the top by a ſmall wooden croſs bar. By theſe upright boards, the axis of the plate is ſupported, and to them the cuſhions are faſtened. When the machine is uſed, the bottom of the frame is faſtened to the table by an iron crank. The conductor in this machine is made of hollow braſs; and is furniſhed with branches extending from its extremities, and approaching very near the circumference of the plate.

An improvement on this machine is thus deſcribed by Mr Walker in his Lectures on Familiar Philoſophy.

Plate CLXXXVII

"It is made of a round plate of thick looking-glaſs, (fig. 6. Plate CLXXXVII.) This plate turns on an axis *a*, ſupported by the mahogany frame *c c c*, by the handle *g*. The rubbers are of red leather ſtuffed with curled hair, and nailed to thin ſlips of wood, *d d*, one on each ſide of the glaſs, and made to preſs the glaſs very cloſe by the ſcrews *x x*; to theſe rubbers are attached oiled ſilk curtains, *z z*, on both ſides of the glaſs. The conductor, *w w w*, is of braſs and fixed to the frame, *c c c*, by the glaſs ſupporter *q*, which inſulates the conductor *w*, and terminates in the two knobs, *s s*; into theſe knobs are ſcrewed ſmall cylinders of braſs, with a number of points that nearly touch the glaſs, and receive the electric matter from it; they cannot be ſeen in the drawing, being behind the curtains. For exciting poſitive electricity in all kinds of weather and ſituations, this is the moſt powerful and convenient machine ever yet invented"†.

48
Machine in Teyler's muſeum at Haarlem.

A very powerful machine, in which plates of glaſs are employed, is that in Teyler's muſeum at Haarlem, conſtructed by Mr John Cuthbertſon. It conſiſts of two circular plates of glaſs, each 65 inches in diameter, and made to turn upon the ſame horizontal axis, at the diſtance of $7\frac{1}{2}$ inches from one another. Theſe plates are excited by eight rubbers, each $15\frac{1}{2}$ inches long. Both ſides of the plates are covered with a reſinous ſubſtance to the diſtance of $16\frac{1}{2}$ inches from the centre, both to render the plates ſtronger, and likewiſe to prevent any of the electricity being carried off by the axis. The prime conductor conſiſts of ſeveral pieces, and is ſupported by three glaſs pillars 57 inches in length. The plates are made of French glaſs, as this is found beſt next to the Engliſh flint which could not be procnred of ſufficient ſize. The conductor is divided into branches which enter between the plates, but collect the fluid by means of points only from one ſide of the plate. The force of two men is required to work this machine; but when it is required to be put in action for any length of time, four are neceſſary.

By this machine Van Marum made his experiments on metals, &c. which will be mentioned hereafter.

49
Van Marum's new machine.

Plate CXC.

Within theſe few years, Dr Van Marum has conſtructed a new machine, of ſmaller dimenſions, but of much greater *proportional* power than the preceding. It is thus deſcribed in Nicholſon's Journal. Fig. 75. Pl. CXC. exhibits a perſpective view of the machine, and fig. 76, 77, 78, 79, a ſection, excluſive of the cuſhions. In the view it may be obſerved that the cuſhions are each ſeparately inſulated upon pillars of glaſs, and are applied nearly in the direction of the horizontal diameter of the plate, inſtead of the vertical diameter as heretofore. The ball diametrically oppoſite to the handle is the prime conductor, and the ſemicircular piece with two cylindrical ends ſerves, in the poſition of the drawing, to receive the electricity from the plate. By the happy contrivance of altering the poſition of this ſemicircular branch from vertical to nearly horizontal, the cylindrical ends may be placed in contact with the cuſhions, and the prime conductor inſtantly exhibits negative electricity. But as it is neceſſary that the cuſhions ſhould communicate with the ground when the poſitive power is wanted, and that they ſhould be inſulated when the negative power is required, there is another ſemicircular branch applied to the oppoſite ſide of the plate nearly at right angles to the firſt. That is to ſay, when poſitive electricity is wanted, this ſecond branch denoted by I, I in the ſection fig. 76. is placed nearly horizontal, and forms a communication from the cuſhions to the ground through a metallic rod from K behind the mahogany pillar which ſupports the axis; but when, on the contrary, the negative power is wanted, and the branch from the prime conductor is placed in contact with the cuſhions, this other branch from the axis is put into the vertical ſituation, and carries off the electricity emitted from the plate of glaſs.

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† *Walker's Lect.* vol. ii. 2d edit.

The axis of the plate B *h*, fig. 76. is ſupported by a ſingle column A, which for that purpoſe is provided with a bearing-piece K, on which two braſs collar-pieces DD, repreſented more at large and in face in fig. 78. are fixed, and carry the axis itſelf. The whole of fig. 76. is reduced to one 16th of its real dimenſions, unleſs contracted by the ſhrinking of the paper after printing; to obviate which, it may be remarked that the diameter of the plate is 31 Engliſh inches. The axis has a counterpoiſe O, of lead, to prevent too great friction in the collar D neareſt the handle. The arc of the conductor EE, which carries the two ſmall receiving conductors FF, is fixed to the axis G, which turns in the ball H. On the other ſide of the plate is ſeen the other arc I I, of braſs wire, half an inch in diameter, fixed to the extremity of the bearing-piece K, ſo that it may be turned in the ſame manner as the arc EE. The two receiving conductors FF are ſix inches long, and two and a half inches in diameter. The double line P repreſents a copper tube terminating in a ball Q. It moves like a radius upon the ſtem R of the ball S, which being ſcrewed into the conductor H, ſerves to confine the arm P in any poſition which may be required. The diameter of the ball S is only two inches, which, together with certain other leſs rounded parts of this apparatus, may ſerve to ſhow that the conſiderable electricity from this machine is leſs diſpoſed to eſcape than if it had proceeded from a cylinder. The diſſipation of electricity along the glaſs ſupports is prevented by a kind of cap T, of mahogany, which affords an electrical well or cavity underneath, and likewiſe effectually covers the metallic caps into which the glaſs is cemented. The lower extremity of the cap is guarded in the ſame manner by a hollow piece or ring V, of mahogany, which covers the metallic ſocket into which the glaſs is cemented. The three glaſs pillars are ſet in ſliding-pieces, as marked on the platform of fig. 75, which are nine inches long.

The rubbers of this machine differ in no eſſential particular from thoſe deſcribed by the inventor in the Journal de Phyſique for February 1791; and the apparatus for applying them is deſcribed in the ſame work for April 1789. Fig. 77. repreſents a ſection of this judicious piece of mechaniſm ſeen from above, and one-fourth of the real ſize. A metallic ſliding-piece *bb*, is ſlided into a correſpondent face, on the ball Z, which is one of thoſe fixed on the top of the glaſs pillars near the circumference of the glaſs plate in fig. 75. To this is affixed the piece *dd*, which terminates in two hinges *gg*, that allow the ſprings *ee* to move in the plane of the horizon. The pieces *gg* repreſent the wood-work of the cuſhions attached to the extremities of the ſprings by the hinges *hh*. The ſprings are regulated by the bolt and ſcrew *ii*. The two cuſhions are thus made to apply to the plate equally through their whole length; the actions on the oppoſite ſides of the plate are accurately the ſame; and the play of the hinges *gg*, prevents the plate from being endangered by any ſtrain in the direction of its axis. It is certain that, before this adequate proviſion was made to ſecure thoſe eſſential requiſites, it was impracticable to apply the cuſhions to a plate with the ſame ſafety and effect as to cylinders, which poſſeſs much ſtrength from their figure. An ingenious workman will probably find little difficulty in conſtructing theſe rubbers from this deſcription and drawing; but the moſt preciſe information reſpecting every circumſtance and dimenſions is to be found in the letters above quoted.

The inner extremities of the cuſhions are defended by the plates of gum-lac YY, which cover the three ſides or edges, and prevent their attracting the electric power from the ends of the receiving conductor.

The part of the axis which moves between the collars is made of ſteel. The middle of the non-conducting part of the axis is a cylinder of walnut-tree *aaaa*, baked until its inſulating power is equal to that of glaſs, and then ſoaked in amber varniſh, while the wood ſtill remains hot. The two extremities of this cylinder, which are of a leſs diameter, are forced, by ſtrong blows, with a mallet, into the ſtout braſs caps *b* and *c*, in which they are retained by three iron ſcrews *dd*. The cylinder *aa*, and the braſs caps, are covered with a layer of gum-lac *eeee*, to preſerve the inſulating ſtate of the wooden cylinder more perfectly, and to prevent the cap *b* from throwing flaſhes to the rubbers. The bottom of the cap *b* is ſcrewed home on the capped extremity of the ſteel axis *b*. The baſe of the cap *c*, which is four inches in diameter, terminates in an axis one inch thick, and two in length; the extremity of which is formed into a ſcrew. The glaſs plate is put on this projecting part, and ſecured in its place by a nut of box-wood, forced home by a key, applied in the holes *ii*. Two rings of felt are applied on each ſide of the glaſs, to defend its ſurface from the contact of the wood and the metal; and the central hole in the glaſs, which is two inches in diameter, contains a ring of box-wood, which prevents its immediate application to the axis.

As it is neceſſary that the axis G ſhould be parallel to the axis of the plate, in order that the conductors FF may move parallel to the plate itſelf, the pillar M is rendered adjuſtable by three bearing ſcrews RR at the bottom, which re-act againſt the ſtrong central ſcrew T, and this is drawn downwards by its nut. The conductors FF are alſo adjuſtable by the ſliding-pieces *vv*, and the binding-ſcrews *ww*, which alſo afford an adjuſtment to bring the axis of each ſmall conductor parallel to the face of the glaſs plate. A ſimilar adjuſtment may be obſerved at the extremities of the arc II.

Fig. 79. repreſents a ſection of the moving part of the branch II, one-half of its real ſize. A braſs plate αα is ſcrewed to the face of the capital K by three iron ſcrews β. To this is ſcrewed another ring δδ, which affords a groove for the moveable ring γγ, into which the arms II are fixed. This is accordingly applied in its place before the ring δδ is fixed.

The wooden part of the rubbers GG, fig. 77. is covered with thin plates of iron, excepting the ſurface neareſt to the glaſs. The intention of this is to maintain a more perfect communication between the rubbed part of the cuſhion and the earth or negative conductor, as the caſe may be.

The plates of gum-lac YY, are applied to the rubbers, each by means of a thin plate of braſs, to which they are affixed by heat. There are two wires rivetted in the plates, which are thruſt into correſpondent holes in the wooden part of the cuſhion.

The mahogany column A ends in a ſquare ζζ, upon which

which the piece K is fitted and firmly applied, by means of the ſcrew and nut exhibited in the ſection. †

The following deſcription of a uſeful machine is taken from Mr Cavallo, who conſiders it as one of the moſt complete with which he is acquainted.

The frame of this machine conſiſts of the bottom board ABC, which when the machine is to be uſed, is faſtened to the table by two iron clamps, one of which appears in the figure near C. Upon the bottom board are perpendicularly raiſed two ſtrong wooden pillars KL, and AH, which ſupport the cylinder, and the wheel. From one of the braſs caps of the cylinder FF, an axle of ſteel proceeds, which paſſes quite through a hole in the pillar KL, and has on this ſide of the pillar a pulley I, fixed upon its ſquare extremity. Upon the circumference of this pulley there are three or four grooves, in order to ſuit the variable length of the ſtring *a b*, which goes round one of them, and round the groove of the wheel D. The other cap of the cylinder has a ſmall cavity, which fits the conical extremity of a ſtrong ſcrew, that proceeds from the pillar H. The wheel D, which is moved by the handle E, turns round a ſtrong axle, proceeding from almoſt the middle part of the pillar KL.

The rubber G of this machine is on each end two or three inches ſhorter than the cylinder (i. e. the cylinder excluſive of the necks), and it is made to rub about one-tenth part of the cylinder's circumference, or rather leſs; it conſiſts of a thin quilted cuſhion of ſilk, ſtuffed with hair, and faſtened by ſilk ſtrings upon a piece of wood, which is properly adapted to the ſurface of the cylinder. And to the lower extremity of the cuſhion, or rather of the piece of wood to which the cuſhion is tied, a piece of leather is faſtened, which is turned over the cuſhion, i. e. ſtands between it and the ſurface of the cylinder, and to the extremity of which a piece of ſilk or oiled ſilk is faſtened, which covers almoſt all the upper part of the cylinder. Upon this leather, which reaches from the lower to almoſt the upper extremity of the cuſhion, ſome of the amalgam is to be worked, ſo as to be forced as much as poſſible into its ſubſtance: if moſaic gold is to be tried, then the leather ſhould be new, and whereon no other amalgam has been put. This rubber is ſupported by two ſprings, ſcrewed to its back, and from which it may be eaſily unſcrewed, when occaſion requires it. The two ſprings proceed from the wooden cap of a ſtrong glaſs pillar, perpendicular to the bottom board of the machine. This pillar has a ſquare wooden baſis, that ſlides in two grooves in the bottom board ABC, upon which it is faſtened by a ſcrew. In this manner the glaſs pillar may be faſtened at any required diſtance, and in conſequence the rubber may be made to preſs harder or lighter upon the cylinder. The rubber in this manner is perfectly inſulated; and, when inſulation is not required, a chain with a ſmall hook may be hanged to it, ſo as to have a regular communication with the piece of leather; the chain then falling upon the table, renders the rubber uninſulated.

Fig. 7. repreſents the prime conductor AB belonging to this machine. This is of hollow braſs, and is ſupported by two glaſs pillars varniſhed, that by two braſs ſockets are fixed in the board CC. This conductor receives the electric power through the points of the collector L, which are ſet at about half an inch diſtance from the ſurface of the cylinder of the machine.

If the handle E of the wheel, be turned (and on account of the rubber it ſhould be turned always in the direction of the letters *a b c*) this machine ſtanding in the ſituation that is repreſented in the figure, will give poſitive electricity, i. e. the prime conductor will be electrified poſitively. But if a negative electricity be required, then the chain muſt be removed from the rubber, and hung to the prime conductor; for in this caſe the electricity of the prime conductor will be communicated to the ground, and the rubber remaining inſulated, will appear ſtrongly negative. Another conductor, equal to the conductor AB, may be connected with the inſulated rubber, and then the operator may obtain as ſtrong negative electricity from this, as he can poſitive from the conductor AB.

50
Mr Nairne's machine.
Fig. 8.

The next machine which we ſhall mention is one invented by Mr Nairne, which is chiefly employed for medical purpoſes; but a modification of which, to be preſently deſcribed, will anſwer for moſt purpoſes of electrical experiment better than any other.

The cylinder in Mr Nairne's machine is about twelve inches long and ſeven in diameter; it turns upon two wooden pieces cemented on the top of two ſtrong glaſs pillars, BB. Theſe pillars are made faſt into the bottom board of the machine, which is faſtened to the table by means of a crank. There are grooves made in the under part of the bottom of the crank, through which the pieces FE ſlide. On theſe pieces the pillars ſtand by which the two conductors are ſupported; and in order to place theſe conductors nearer to the cylinder, or remove them farther from it, the pieces on which they ſtand are moveable inwards or outwards, and may be fixed by the two ſcrew nuts LL. The rubber is faſtened to the conductor R; and conſiſts of a cuſhion of leather ſtuffed, having a piece of ſilk glued to its under part. This laſt being turned over the ſurface of the cuſhion, and thus interpoſed between it and the glaſs, goes over the cylinder, and almoſt touches the pointed wires which are fixed on the other conductors. The conductors are of tin covered with black lacquer, each of them containing a large coated glaſs jar, and likewiſe a ſmaller one, or a coated tube, which are viſible when the caps NN are removed. To each conductor is fixed a knob O, for the occaſional ſuſpenſion of a chain to produce poſitive or negative electricity. The part of the winch C, which acts as a lever in turning the cylinder, is of glaſs. Thus every part of the machine is inſulated, the cylinder itſelf and its braſs caps not excepted. And to this the inventor has adapted ſome flexible conducting joints, a diſcharging electrometer, and other utenſils neceſſary for the practice of medical electricity.

A modification of this machine is repreſented at fig. 9.

a, the handle of the cylinder.
b, the *negative*, and *c*, the *poſitive* conductor.
d, the ſilk flap of the rubber.

51
Mr Reid's portable machine.
Fig. 10.

Mr Reid's portable machine, as improved by Mr Lane, is the laſt which we ſhall deſcribe, and is repreſented at fig. 10. A is the glaſs cylinder, moved vertically by means of the pulley at the lower end of the axis,

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† Nicholſon's Journ, 4to. vol. i. p. 84.

axis. This pulley is turned by a large wheel B, which lies parallel to the table. There are three pulleys of different dimenſions marked in the figure; one of which revolves four times for every revolution of the large wheel B. The conductor C, is furniſhed with points to collect the fluid, and is ſcrewed to the wire of a coated jar D, which ſtands in a ſocket between the cylinder and the wheel. This figure alſo ſhews how Mr Lane's electrometer, to be afterwards deſcribed, may be adapted to this machine.

A great many other machines have been deſcribed in the Philoſophical Tranſactions, Journal de Phyſique, and in various books on electricity; but thoſe of which we have given an account are the moſt material.

CHAP. III. *General directions for uſing the Electrical Machine.*

52 It is of the greateſt conſequence that the machine, as well as the table on which it ſtands, and every thing in its neighbourhood, be perfectly free from duſt; it is therefore neceſſary to begin by wiping every part of the machine, &c. with a clean, dry, ſoft linen cloth. If the weather is not warm and dry, it will be proper alſo to place the machine for ſome time before the fire, that it may be perfectly free from moiſture. The cylinder if uſed lately and not cleaned, may have contracted ſpots of dirt or greaſe; in which caſe it muſt be rubbed with a ſoft rag dipped in ſpirit of wine. In ſhort, very much depends on the machine being quite free from dirt and moiſture.

53 The conductors are now to be fixed in a proper ſituation, ſo that the rubber of the negative conductor may preſs cloſely to the cylinder on one ſide, and the points of the poſitive conductor may approach on the other as near to it as poſſible, without touching. Then while the cylinder is made to revolve, the amalgam is to be applied to it, where it is not covered with the ſilk; this is beſt done by means of a piece of leather to which the amalgam has been previouſly faſtened, which is a better method than by ſpreading it on the rubber. As the amalgam is liable to oxidation from expoſure to the air, it is proper to ſcrape the ſurface of it before it is applied to the cylinder; and if any old amalgam has been left on the cuſhion of the rubber, this ſhould alſo be ſcraped before uſing the new.

54 After having made theſe arrangements, on whirling the cylinder in contact with the rubber, without bringing any conducting body near the former, or inſulating the latter, we will perceive in the dark a ſtream of fire iſſuing from the place of contact between the rubber and the cylinder, and adapting itſelf to the form of the cylinder, ſo as to involve it in a blue flame mixed with bright ſparks; the whole making a very perceptible whizzing and ſnapping noiſe. If the finger is brought near the cylinder in this ſituation, the flame and ſparks will leave the cylinder and ſtrike the finger; and this phenomenon will continue as long as the globe continues to be whirled round.

On applying the prime conductor, the light will vaniſh, and be perceptible only upon the points preſented to it by the cylinder; but if the finger is now brought near the conductor, a very ſmart ſpark will ſtrike it, and that at a greater or ſmaller diſtance, according to the ſtrength of the machine. This ſpark, when the electricity is not very ſtrong, appears like a ſtraight line of fire; but if the machine acts very powerfully, it will put on the appearance of zig-zag lightning, throwing out other ſparks from the corners, and ſtrike with ſuch force as to give conſiderable pain to thoſe who receive it.

55 If theſe appearances do not take place, or if they take place only in a ſlight degree, ſoon after the applying the amalgam, ſpread a little oil on the palm of your hand, and let it ſlightly touch the cylinder as it moves round; in general this is inſtantly followed by a copious emiſſion of ſparks, numerous torrents of which will now paſs from the edge of the ſilk to the knuckles. Sometimes, however, after uſing all theſe precautions, the machine does not act well, and in this caſe the rubber ſhould be examined, to ſee if ſomething is not wrong there. The rubber ſhould be removed from the glaſs pillar or the negative conductor, to which it is faſtened, by taking out the ſcrews by which it is uſually ſecured; it is then to be brought near the fire ſo that the ſilk may be perfectly dried, after which a little tallow or ſuet ſhould be rubbed upon the cuſhion, and it ſhould then be replaced in its ſituation. If the ſilk of the rubber is fitted to the cuſhion by means of a wire as deſcribed in (42.) it will only be neceſſary to take out this wire, in order to dry the ſilk.

56 While both conductors remain inſulated, the machine will not continue to act long, or at leaſt its action will be much leſs powerful; but if the negative conductor or rubber be made to communicate with the floor or a moiſt wall, it will in general continue its action for any length of time required.

57 The weather is found to have conſiderable influence on the action of an electrical machine; in wet weather it will neither act ſo powerfully, nor for ſo long a time as when the weather is moderately warm and dry, unleſs perpetual care be taken to keep every part of it warm and clean. Very hot dry weather is alſo unfavourable to the action of the machine, and when this happens, even the floor of the room may be too dry to ſerve as a conductor; it is then neceſſary to connect the rubber by a chain which communicates with ſome moiſt ſurface, as a cellar, a pump, or the like.

58 Mr Nicholſon's directions for increaſing the power of the cylinder.

Mr Nicholſon lays down the following directions for preparing the machine for experiment.

Clean the cylinder, and wipe the ſilk.

Greaſe the cylinder, by turning it againſt a greaſed leather till it is uniformly obſcured. I uſe the tallow of a candle.

Turn the cylinder till the ſilk flap has wiped off ſo much of the greaſe as to render it ſemitranſparent.

Put ſome amalgam on a piece of leather, and ſpread it well ſo that it may be uniformly bright. Apply this againſt the turning cylinder. The friction will immediately increaſe, and the leather muſt not be removed until it ceaſes to become greater.

Remove the leather, and the action of the machine will be very ſtrong.*

CHAP. IV. *An Enumeration of ſome other Parts of an Electrical Apparatus to be deſcribed hereafter.*

THERE are many other parts of the electrical apparatus; but theſe we can only enumerate here, as their deſcription and uſe will come more properly to be explained

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* *Phil. Tranſ.* for 1789.

plained under the principles on which they are conſtructed.

Fig. 12. and 13. repreſent different forms of coated jars or Leyden phials employed for the accumulation of the electric power, and the uſual forms of the diſcharging rod.

Fig. 14. ſhews one of the moſt approved forms of the electrical battery.

Fig. 15. repreſents a ſtand ſupporting four electrometers for aſcertaining the preſence and meaſuring the degree of electricity.

Fig. 17. exhibits the uſual form of the quadrant electrometer invented by Mr Henly, placed on the end of the prime conductor.

Fig. 18. repreſents Mr Bennet's gold-leaf electrometer.

Fig. 19. ſhews Mr Cavallo's pocket electrometer.

Fig. 29. repreſents Mr Henly's univerſal diſcharger; and fig. 30. a preſs belonging to it.

Fig. 31. and 32. ſhew an outline of Mr Morgan's diſcharging rod.

Fig. 42. repreſents Mr Nicholſon's inſtrument for diſtinguiſhing poſitive and negative electricity.

Fig. 67. gives a view of Lane's electrometer.

Fig. 68. and 69. repreſent Mr Brooke's electrometer as made by Mr Adams.

Fig. 70. repreſents Cuthbertſon's compound or univerſal electrometer.

Fig. 71. and 72. are two views of Dr Robiſon's comparable electrometer.

Fig. 73. illuſtrates the mode of uſing the electrophorus.

Fig. 80. is a figure of an electrical machine in which ſilk is employed as an electric inſtead of glaſs.

Fig. 85. repreſents Bennet's doubler, and fig. 86. Nicholſon's revolving doubler.

The reſt of the apparatus figured in the plates will be enumerated and fully deſcribed in the ſucceeding parts of the article.

Beſides the apparatus which we have deſcribed and enumerated, the electrician ſhould have ſeveral glaſs tubes, ſome of ſmooth and others of rough glaſs, ſticks of ſealing wax, a piece of yellow amber, &c. for exciting poſitive and negative electricity, when theſe two ſtates are to be obſerved or compared.

It is of ſome conſequence that an electrician ſhould have ſome mechanical taſte; as he may often be required to renew or repair parts of his apparatus, either to ſave expence, or when he is at a diſtance from a ſkilful workman. For this purpoſe, few tools are neceſſary. The principal are a turner's lathe, for turning caps, balls, pedeſtals, &c.; a blow-pipe with a proper lamp, for bending tubes, or opening and cloſing ſuch as are of large diameter; a few files of various degrees of fineneſs, and various forms, as flat, half-round, rat-tail, &c.

PART III.

AN EXPERIMENTAL ILLUSTRATION OF THE PRINCIPLES OF ELECTRICITY.

59 WE propoſe, in this part, to deſcribe the principal phenomena of *communicated electricity;* and to illuſtrate theſe by experiments, which we ſhall, as nearly as can be done, claſs under certain general heads or principles. After recounting the experiments which illuſtrate each head, we ſhall deſcribe the conſtruction and explain the uſes of the ſeveral electrical inſtruments which depend on the principle laid down. We ſhall alſo take an opportunity, in this part, of tracing the origin and progreſs of the more important diſcoveries which have been made in the experimental part of the ſcience.

As it muſt be ſuppoſed that the reader is at preſent unacquainted with the *theory* of electricity, the principles to which the ſeveral experiments in this part are referred, will be merely ſuch facts or general phenomena as have been obſerved in the courſe of experiment, independently of theory. In the following part of this article, we ſhall endeavour more accurately to illuſtrate theſe phenomena, and explain them according to the moſt generally received theory of electricity.

Chap. I. *Of Electrical Attraction and Repulſion, and the Inſtruments which depend on them.*

60 *An electrified body attracts bodies brought near it, and after holding them in contact with it for ſome time, again repels them.*

Experiment 1.—Suſpend a downy feather by a ſilken thread; on making it approach within a few inches of the prime conductor, while the cylinder is ſet in motion, it will be attracted to the conductor, and almoſt immediately repelled; and thus alternately attracted and repelled, as long as the machine continues to be worked.

This experiment may be thus varied in a pleaſing manner. Take a glaſs tube, no matter whether ſmooth or rough, and, after rubbing it, preſent to it a downy feather; this will, as in the former inſtance, be inſtantly attracted, and be retained for a ſhort time in contact with the tube; when it will be repelled. If, at the time of its repulſion, the tube be held in the air at a diſtance from ſurrounding objects, the repelled feather will float above the tube, and may be driven about the room as long as it does not touch any object in its neighbourhood. If one perſon hold a ſmooth glaſs tube, and another a rough tube or a ſtick of ſealing wax, and a feather be let looſe between them when excited, the feather will leap from one to the other, and thus the two perſons will ſeem to drive it between them like a ſhuttlecock, whence this experiment is called the *electrical ſhuttlecock.*

61 Dancing figures. Plate CLXXXVIII.

Exper. 2.—Let there be two metallic plates, one as *c*, fig. 20. ſupported by a ſtand, ſo as that it may be placed on a table, &c. the other *d* provided with a hook, by which it may be hung by a chain to the prime conductor, at ſome diſtance from the other plate. Then cut ſome ſmall figures of men or other objects in paper, or, what is better, form them out of the dry pith of elder, or of ruſhes, and lay them on the lower plate. On working the machine the figures will riſe from the lower plate, and move perpetually from the one plate to the other as repreſented in the figure.

Exper. 3.—Let a ſolid rod of glaſs, as *a*, fig. 21. be made to paſs through a bell *b*, perforated for the purpoſe, and let one end of the rod be fixed in a wooden foot, while the other ſupports two metallic arms, *c d*, *e f*, croſſing each other, and knobbed at their extremities. From each extremity let a ſmall bell without a clapper be ſuſpended by a metallic wire, and from each arm, at a little diſtance from the extremities, let the clappers of theſe bells be ſuſpended by ſilken threads. On connecting the top of the ſtand with the prime conductor, and ſetting the machine in motion, the clappers will begin to move between the central bell and the other four ſo as to ring the whole five.

Here the bells receive the electric power from the prime conductor, and being electrified, attract and repel the clappers which hang freely between them.

Exper. 4.—Tie a ſmall body, as for inſtance a light piece of cork, to a ſilk thread about eight inches long, and holding the thread by its end, let the ſmall body hang at the diſtance of about eight inches from the ſide of the prime conductor electrified. This ſmall body, if the electrization of the conductor is not ſtrong, will not be attracted. But if a finger or any conducting ſubſtance be preſented to that ſide of the ſmall body which is fartheſt from the prime conductor, then the ſmall body will immediately move toward the prime conductor; and when this body has touched the prime conductor, it will be inſtantly repelled from it, on account of the repulſion exiſting between bodies poſſeſſed of the ſame kind of electricity.

Indeed, if this inſulated body be very near to the prime conductor, or the prime conductor ſtrongly electrified, then the ſmall body will be attracted without preſenting to it any conducting ſubſtance; or the natural fluid belonging to that body will be all crowded on that ſide of it which is neareſt to the prime conductor.

If this ſmall body, inſtead of the ſilk, be ſuſpended by a linen thread, it will be attracted at a much greater diſtance, than in the other caſe.

62 *Bodies in the ſame ſtate of electricity, i. e. which are all electrified poſitively, or all negatively, have a tendency to repel each other.*

Exper. 1.—Stick a downy feather into one of the holes of the prime conductor. When the cylinder is moved the feather will begin to ſwell, and its plumes will ſeparate to a conſiderable diſtance from each other.

This experiment may be varied, by placing the repreſentation of a human head upon the prime conductor. When the cylinder is moved, the hair of the head will briſtle up and ſtand erect as repreſented in fig. 22. Plate CLXXXVIII.

Exper. 2.—Let ſmall balls made of cork or the pith of elder well dried, be ſuſpended from the prime conductor by threads of an equal length. While the cylinder continues at reſt, the balls will touch each other, but as ſoon as the machine is ſet in motion they will repel each other to a greater or leſs diſtance, according as the electric power produced is ſtronger or weaker.

It is not neceſſary that the threads be in contact with the prime conductor, for if the balls be brought near the conductor while the machine is in motion, they will recede from each other as before.

The ſame effect will be produced whether the balls are hung from the poſitive or the negative conductor.

From the circumſtance obſerved in the above experiments we deduce the following important corollary.

63 Corollary. *Objects brought near an electrified body are electrified by poſition.*

The communication of electricity from an electrified body, to another which is not in contact with it, but is only in its vicinity, may for the preſent be conceived by remarking that theſe bodies are ſurrounded with air. Air, although an electric, is not a very perfect electric, but is more or leſs alſo a conductor, eſpecially when it is moiſt. When a body is electrified it communicates to the air in contact with it a portion of its electric power, and thus the air becomes electrified, and of courſe imparts to the bodies, which are ſurrounded by it a degree of electricity; and this the more eaſily as it is in a better conducting ſtate.

The apparent action of the air in communicating electricity to a body which is ſurrounded by it, may be illuſtrated by the following experiments.

Inſulate in a horizontal poſition a metallic rod about two feet long, having blunt ends, and at one of its ends ſuſpend an electrometer, like that repreſented in fig. 116; then bring within three or four inches diſtance of its other end an excited glaſs tube. On the approach of the tube, the balls of the electrometer will open, and if you preſent towards them a body poſitively electrified, you will perceive that they diverge with poſitive electricity. If the tube be removed, the balls come together again, and no electricity remains in them, or in the metallic rod. But if while the tube is near one end of the rod, and the balls diverge with poſitive electricity, the other end of the rod, viz. that from which the electrometer hangs, be touched with ſome conductor, the cork balls will come immediately together, and they will remain ſo when the conductor has been removed;—remove now the excited glaſs tube, and the balls will immediately diverge with negative electricity; which ſhows that the rod remains electrified negatively.

If the above experiment be made with an electric negatively electrified (for inſtance, a rod of ſealing-wax inſtead of the excited glaſs tube) then the apparent electricities in the rod will be juſt the reverſe of what they were before; for in this caſe, that end of the rod to which the electric has been preſented, will be poſitive, and the oppoſite end negative; which oppoſite end, if touched in this ſtate with ſome conducting ſubſtance, will acquire ſome electric power from that ſubſtance; and when, after that ſubſtance has been removed, the excited electric is alſo removed, the rod will remain poſitive.

In making this experiment, care muſt be taken that the end of the rod be very blunt, and that the electric be not very powerfully excited; otherwiſe a ſpark may paſs from this to the rod, which renders the experiment precarious.

Principles of Electricity illuſtrated by experiment.

Take two rods of metal, each about a foot long, furniſhed with knobs at both ends; and, either by ſilk lines or by inſulating ſtools, inſulate them, ſo that they may ſtand horizontally in one direction, and about a quarter of an inch diſtance from one another. To the middle of each of theſe rods hang an electrometer, like that repreſented in fig. 16. This done, take an excited glaſs tube, and bring it to about three inches diſtance from the knob of one of the rods; on doing which, the electrometers of both rods will appear electrified: keep the tube in that ſituation for about two ſeconds, then remove it. The rods now will remain electrified, as appears by the electrometers; the firſt, viz. that to which the excited tube had been preſented, remaining negative, and the other poſitive.

In this experiment, if, inſtead of the glaſs tube, an electric, negatively excited, be brought near the end of one rod, then that rod will be electrified poſitively, and the other negatively.

This is all that we can properly explain at preſent with reſpect to the agency of the air in the production of electrical phenomena. We ſhall take occaſion to conſider this ſubject more fully in a future part of this article, when we ſhall ſee that a variety in the ſtate of the air produces conſiderable diverſity in the phenomena.

On the principle of electric repulſion and the above corollary depend the action of ſeveral inſtruments which are of great uſe in electrical experiments, and which we ſhall now deſcribe.

64 Electroſcopes or electrometer.

Inſtruments which are employed to aſcertain the preſence of electricity are called *electroſcopes.* As they are generally employed to meaſure the degree of electricity produced, they are alſo called *electrometers,* and by this name we ſhall in future diſtinguiſh them.

65 Abbe Nollet's.

The firſt electrometer appears to have been conſtructed by the abbe Nollet; it conſiſted of two threads of ſilk, which, as has been ſhown, recede from each other on the approach of an electrified body. He obſerved the angle of their divergency by its ſhadow caſt on a board placed behind them. Mr Waitz improved this electrometer by appending ſmall weights to the threads *.

66 Mr Canton's electrometer.

Mr Canton contrived an electrometer which is the foundation of thoſe which are now in common uſe. He got a pair of balls turned in a lathe out of the dry pith of elder; theſe he hung by threads of the fineſt linen, and kept them in a narrow box with a ſliding cover, where they were ſo diſpoſed that the threads could lie ſtraight. When he was to uſe it, he held the box by the extremity of the cover, and allowed the balls to hang freely from a pin to which they were fixed †.

Plate CLXXXVII

Fig. 15. repreſents a ſtand ſupporting the electrometers DD, CC. B is the baſis of it, made of common wood. A is a pillar of wax, glaſs, or baked wood. To the top of the pillar, if it be of wax or glaſs, a circular piece of wood is fixed; but if the pillar be of baked wood, that may conſtitute the whole. From this circular piece of wood proceed four arms of glaſs, or baked wood, ſuſpending at their ends four electrometers, two of which, DD, are ſilk threads about eight inches long, ſuſpending each a ſmall downy feather at its end. The other two electrometers, CC, are thoſe with very ſmall balls of cork, or of the pith of elder; and they are conſtructed in the following manner:—*a b* is a ſtick of glaſs about ſix inches long, covered with ſealing-wax, and ſhaped at top in a ring: from the lower extremity of this ſtick of glaſs proceed two fine linen threads (M) *c c*, about five inches long, each ſuſpending a cork or pith-ball *d*, about one-eighth of an inch in diameter. When this electrometer is not electrified, the threads *cc* hang parallel to each other, and the cork-balls are in contact; but when electrified, they repel one another, as repreſented in the figure. The glaſs ſtick *ab* ſerves for an inſulating handle, by which the electrometer may be ſupported, when it is uſed without the ſtand AB.

Another ſpecies of the above electrometer is repreſented in fig. 16; which conſiſts of a linen thread, having at each end a ſmall cork-ball. The electrometer is ſuſpended by the middle of the thread on any conductor proper for the purpoſe, and ſerves to ſhew the kind and quantity of its electricity *.

67 Mr Henley's quadrant electrometer.

Fig. 17. repreſents the quadrant electrometer of Mr Henly, one of the moſt uſeful inſtruments of the kind yet diſcovered, as well for meaſuring the degree of electricity of any body, as to aſcertain the quantity of a charge before an exploſion; and to diſcover the exact time the electricity of a jar changes, when without making an exploſion, it is diſcharged by giving it a quantity of the contrary electricity. The pillar LM is generally made of wood, the graduated arch NOP of ivory, the rod RS is made of very light wood, with a pith ball at the extremity; it turns upon the centre of the ſemicircle, ſo as always to keep near its ſurface; the extremity of the ſtem LM may either be fitted to the conductor or the knob of a jar. When the apparatus is electrified, the rod is repelled by the ſtem, and moves along the graduated arch of the ſemicircle, ſo as to mark the degree to which the conductor is electrified, or the height to which the charge of the jar is advanced.

Beccaria recommends fixing the index between two ſemicircles, becauſe when it is placed over one only, the electricity of this repels and counteracts the motion of the index. Other improvements and variations have been made in this inſtrument, which will be deſcribed hereafter.

The firſt account of Mr Henly's electrometer was given in the Phil. Tranſ. vol. lxii. by Dr Prieſtley, who ſpeaks of it in very high terms in a letter to Dr Franklin. He conſiders it as a perfect inſtrument for meaſuring degrees of electricity, but it will appear hereafter that this is not the caſe.

68 M. Achard's obſervations on the diviſion of the ſcale.

The ſcale in Mr Henly's quadrant is divided into equal parts; but M. Achard has already ſhewn that when this is the caſe, the angle at which the index is held ſuſpended by the electric repulſion is not a true meaſure of the repulſive force; to eſtimate which truly, he demonſtrates that the arc of the electrometer ſhould be

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* *Hiſtoire de l'Electricité.*

† *Phil. Tranſ.* vol. xlix. p. 300.

* *Cavallo's Electricity,* vol. i. p. 168.

(M) Theſe threads ſhould be wetted in a weak ſolution of ſalt.

be divided according to a ſcale of arcs, the tangents of which are in arithmetical progreſſion.

The balls of the ordinary electrometer may be made of *pith* or of *cork*, but the latter muſt be very ſmooth and well poliſhed. They are beſt made in a turner's lathe. They may be made of any ſhape, provided they are regular and free from edges. A very convenient electrometer is made of two long, ſlender pieces of ruſh pith, made and appended to ſhort threads of flax. Theſe may eaſily be hung parallel to each other, whereas in the uſual ball-electrometers the threads to which the balls are hung form an angle with each other. This paralleliſm of the threads is of advantage, and was conſidered of ſo much conſequence by Lord Stanhope (better known to electricians by the title of Lord Mahon) that he was at great pains to ſuſpend his balls in a parallel poſition.

69
Mr Bennet's electrometer.

Of all the inſtruments by which it has been attempted to meaſure electricity, none have been found to anſwer the purpoſe better than that invented by Mr Bennet, and which is repreſented in fig. 18. It conſiſts of two ſlips of gold leaf, *a a*, ſuſpended in a glaſs cylinder *b*. The foot, *c*, may be made of wood or metal, and the cap, *d*, ſhould be of metal; the latter being made flat at top for the convenience of putting any thing upon it that is to be electrified. The cap is about an inch wider than the diameter of the glaſs, and its rim about three quarters of an inch broad, hanging parallel to the glaſs to keep it ſufficiently inſulated, and to turn off the rain, when the inſtrument is employed in experiments on atmoſpherical electricity. Within this is another circular rim about half as broad as the former, lined with ſilk or velvet, ſo that it may be made to fit the outſide of the glaſs exactly, while the cap may be eaſily taken off to repair any damage done to the gold leaf. From the centre of the cap hangs a tin tube ſomewhat longer than the depth of the inner rim, in which a ſmall peg, *f*, is placed, which may be taken out occaſionally. To this peg, which is rounded at one end and flat at the other, two ſlips of gold leaf are faſtened with paſte, gum water, or varniſh. They are about a fifth part of an inch broad and two inches long, and are generally made tapering to a point. In one ſide of the cap is a ſmall tube, *g*, to place wires in; *h*, *h*, are two long pieces of tin-foil faſtened with varniſh on oppoſite ſides of the internal ſurface of the glaſs, where the ſlips of gold leaf may be expected to ſtrike, and in connexion with the foot of the inſtrument. The upper end of the glaſs is covered and lined with ſealing-wax as low as the outer rim, in order to make the inſulation more complete.

70
Improvement of this inſtrument.

An improvement on this electrometer is to make the cylinder pretty long, and to have a ſmall additional tube of gum lac on the end of it. The ſlips of tinfoil reach almoſt to the edge of the outer rim, and are ſharp pointed at the top, widening in the middle and decreaſing in breadth again as they deſcend.

71
Advantages of this inſtrument.

The great advantage of this inſtrument over the electrometers which we have deſcribed above is its extreme ſenſibility, which will appear from the following examples.

72
Its extreme ſenſibility.

1. On putting powdered chalk into a pair of bellows and blowing it upon the cap, this was electrified poſitively when the nozzle of the bellows was about ſix inches from it; but at the diſtance of three feet from the nozzle, the ſame ſtream electrified the cap negatively. Thus it appears that the electricity may be changed from poſitive to negative merely from the circumſtance of this ſtream of chalk being more widely diffuſed in the air. It may alſo be changed by placing a bunch of fine wire, ſilk, or feathers, in the nozzle of the bellows: and it is likewiſe negative when the air is blown from a pair of bellows wanting the iron pipe, ſo that it may come out in a larger ſtream; but this laſt experiment ſucceeded beſt when the air was damp. There is likewiſe a remarkable difference between the experiments in which the electricity is poſitive and that in which it is negative; the former being communicated to the cap with ſome degree of permanency, ſo that the ſlips of gold leaf continue for ſome time to diverge; but the latter being only momentary, and the ſlips collapſing as ſoon as the cloud of chalk is diſperſed. The greater permanency of the electricity in the former caſe is owing to ſome of the chalk ſticking to the cap when the nozzle of the bellows is very near it.

2. A piece of chalk drawn over a bruſh, or powdered chalk put into the bruſh, and projected upon the cap, electrifies it negatively; but its electricity is not communicated.

3. Powdered chalk blown with the mouth or bellows from a metal plate placed upon the cap, communicates to the cap a permanent poſitive electricity. If the chalk is blown from the plate either inſulated or not ſo, that the powder may paſs over the cap, if not too far off, the electricity communicated is alſo poſitive; or if a bruſh be placed upon the cap and a piece of chalk be drawn over it, the ſlips of gold-leaf when the hand is withdrawn gradually open with poſitive electricity as the cloud of chalk diſperſes.

4. Powdered chalk falling from one plate to another placed upon the inſtrument electrifies it negatively.

Other methods of producing electricity with chalk and other powders have been tried; as projecting chalk from a gooſe wing, chalking the edges of books and clapping the leaves of the book ſuddenly together, alſo ſifting the powder upon the cap, all which electrified it negatively; but the inſtrument being placed in a duſty road, and the duſt ſtruck up with a ſtick near it, electrified it poſitively. Breaking the *glaſs-tear* upon a book electrified it negatively, but when broken in water it did not electrify it.

Wheat flour and red lead produced a ſtrong negative electricity in all caſes where the chalk produced a poſitive electricity. The following powders were like chalk: red ochre, yellow roſin, coal aſhes, powdered crocus metallorum, aurum moſaicum, black-lead, lamp-black (which was only ſenſible in the two firſt methods), powdered quick-lime, umber, lapis calaminaris, Spaniſh brown, powdered ſulphur, flowers of ſulphur, iron filings, ruſt of iron, ſand. Roſin and chalk, ſeparately alike, were changed by mixture; this was often tried in dry weather, but did not ſucceed in damp; white-lead alſo ſometimes produced poſitive and ſometimes negative electricity when blown from a plate.

If a metal cup be placed upon the cap with a red hot coal in it, and a ſpoonful of water be thrown in, it electrifies it negatively; and if a bent wire be placed in the cap, with a piece of paper faſtened to it to increaſe its ſurface, the poſitive electricity of the aſcending

ing vapour may be tried by introducing the paper into it.

73 Its ſenſibility increaſed by a lighted candle.

The ſenſibility of this electrometer may be conſiderably increaſed by placing a candle on the cap. By this means, a cloud of chalk, which in the other caſe only juſt opens the gold-leaf, will cauſe it to ſtrike the ſides for a long time together; and the electricity which was not before communicated, now paſſes into the electrometer, cauſing the gold-leaf to repel after it is carried away. Even ſealing-wax by this means communicates its electricity at the diſtance of 12 inches at leaſt, which it would ſcarcely otherwiſe do by rubbing upon the cap.

A cloud of chalk or wheat flour may be made in one room, and the electrometer with its candle be afterwards leiſurely brought from another room, and the cloud will electrify it before it comes very near. The air of a room adjoining to that wherein the electrical machine was uſed, was very ſenſibly electrified, which was perceived by carrying the inſtrument through it with its candle.

No ſenſible electricity is produced by blowing pure air, by projecting water, by ſmoke, flame, or exploſions of gun-powder.

A book was placed upon the cap, and ſtruck with ſilk, linen, woollen, cotton, parchment, and paper, all which produced negative repulſion; but when the other ſide of the book was ſtruck with ſilk, it became poſitive; this ſide, ſtruck at right angles with the former, was again negative; and by continuing the ſtrokes which produced poſitive, it changed to negative for a little while; and by ſtopping again, became poſitive. No other book would do the ſame, though the ſides were ſcraped and chalked, upon a ſuppoſition that altering the ſurface would produce it. At laſt, one ſide of a book was moiſtened, which changed it; whence it was concluded, that one edge of the book had lain in a damp place; which conjecture was farther confirmed by all the books becoming poſitive in damp weather, and one of them being dried at the fire again became negative.

When the cap is approached with excited ſealing-wax, the gold-leaf may be made to ſtrike the ſides of the glaſs more than twelve times; and as the ſealing-wax recedes, it ſtrikes nearly as often; but if it approaches much quicker than it recedes, the ſecond number will ſometimes be greater.

The quantity of electricity neceſſary to cauſe a repulſion of the gold-leaf is ſo ſmall, that the ſharpeſt points or edges do not draw it off without touching; hence it is unneceſſary to avoid points or edges in the conſtruction of this inſtrument.

To the experiments on blowing powders from a pair of bellows, it may be added, that if the powder is blown at about the diſtance of three inches upon a plate which is moiſtened or oiled, its electricity is contrary to that produced by blowing upon a dry plate. This ſhews that the electricity of the ſtreams of powder iſſuing out of the bellows is only contrary to the more expanded part, becauſe it is within the influence of its own atmoſphere; for when this is deſtroyed by the adheſion of the powder to the moiſtened place, it is negative when the bellows are poſitive, as it was before poſitive when the more expanded cloud was negative.

This inſtrument is alſo free from an inconvenience which attends the electrometers in which cork or pith balls are employed. In theſe, when the balls are electrified, they are very apt to adhere together for ſome time before the repulſion takes place, and then they often ſeparate with a jerk ſo as to recede from each other farther than they ought to do, and thus make the electricity produced appear greater than it really is; whereas the ſlips of gold-leaf in Bennet's electrometer do not adhere together, and ſeparate equally and gradually.

74 Its defects.

75 Cavallo's mode of remedying theſe defects.

This inſtrument is, however, not without its defects, as the delicate texture of the gold-leaf renders it very difficult to faſten the ſlips, ſo as to keep them entire, and alſo prevent the inſtrument from being eaſily removed from one place to another. Mr Cavallo propoſes to remedy theſe defects in the following manner: When the ſlips are cut and are lying upon paper, or on the leather cuſhion upon which they are cut, make them equal in length, by meaſuring them with a pair of compaſſes, and cutting off a ſuitable portion from the longeſt; then cut two bits of very fine gilt paper, each about half an inch long, and a quarter of an inch broad, and by means of a little wax, ſtick one of them to one extremity of each ſlip of gold-leaf, ſo as to form a kind of letter T. This done, hold up in the fingers of one hand, one of thoſe pieces of paper with gold-leaf ſuſpended to it, and hold the other with the fingers of the other hand; then bringing them near to each other, and having adjuſted them properly, viz. ſo as to let them hang parallel and ſmooth, force the pieces of paper which now touch each other, between the two ſides of a ſort of pincers made of braſs wire, or of very thin and hammered braſs plate, which pincers are faſtened to the under part of that piece which forms the top or cover of the glaſs veſſel. As theſe gold ſlips are very apt to be ſpoiled, we ſhould keep ſeveral of them ready cut in a book, each having a croſs piece of paper faſtened to one extremity, ſo that in caſe of accident, a new pair of gold ſlips may be ſoon put between the aperture of the above-deſcribed pincers; and by this means the electrometer is rendered, in a certain manner, portable.

76 Mr Cavallo's pocket electrometer.

Mr Cavallo deſcribes an electrometer which is nearly as ſenſible as Mr Bennet's, and is not liable to the inconveniences above mentioned. It is repreſented at fig. 19.

The caſe or handle of this electrometer is formed by a glaſs tube, about three inches long, and three-tenths of an inch in diameter, half of which is covered with ſealing-wax. From one extremity of this tube, i. e. that without ſealing wax, a ſmall loop of ſilk proceeds, which ſerves occaſionally to hang the electrometer on a pin, &c. To the other extremity of this tube a cork is adapted, which, being cut tapering on both ends, can fit the mouth of the tube with either end. From one extremity of this cork, two linen threads proceed, a little ſhorter than the length of the tube, ſuſpending each a little *cone* of pith of elder. When this electrometer is to be uſed, that end of the cork which is oppoſite to the threads is puſhed into the mouth of the tube; then the tube forms the inſulated handle of the pith electrometer, as repreſented fig. 19. *c*. But when the electrometer is to be carried in the pocket, then the threads are put into the tube, and the cork ſtops it, as repreſented at *b*. The peculiar advantages

tages of this electrometer are, its convenient ſmall ſize, its great ſenſibility, and its continuing longer in good order than any other we have yet ſeen.

a, Repreſents a caſe to carry the above-deſcribed electromer in. This caſe is like a common tooth-pick caſe, except that it has a piece of amber fixed on one extremity A, which may occaſionally ſerve to electrify the electrometer negatively, and on the other extremity it has a piece of ivory faſtened upon a piece of amber BC. This amber BC ſerves only to inſulate the ivory, which, when inſulated, and rubbed againſt woollen cloths, acquires a poſitive electricity; and it is therefore uſeful to electrify the electrometer poſitively.

There are many other electrometers employed by electricians; but theſe cannot properly be deſcribed at preſent, as they are conſtructed on principles which have not yet been explained. They will be noticed in their proper place.

77 Capillary ſyphon. *The electric power forces a fluid to flow in a ſtream through a capillary tube, through which, when not electrified, it would only paſs in drops.*

Exper. 1.—Suſpend a ſmall metallic bucket full of water from the prime conductor, and place in the water a glaſs ſyphon, the diameter of whoſe tube is ſo ſmall that the water will only drop from it. Now ſet the cylinder of a machine in motion, and the water will begin to flow in a full ſtream from the end of the ſyphon. The ſtream will ſometimes be ſubdivided, and if the experiment is made in the dark, the water will appear luminous.

Exper. 2.—Dip a ſponge in water, and ſuſpend it from the prime conductor. The water which before only dropped from the ſponge, will now flow very faſt, and appears in the dark like fiery rain.

The effect of electricity on water flowing through capillary tubes, was firſt obſerved by M. Boze, but was more accurately inveſtigated by the Abbé Nollet. He found that the ſtream of water through a capillary tube, was accelerated in the inverſe ratio of the diameter of the tube; but that if the diameter of the tube, was leſs than a line; the ſtream was not ſenſibly accelrated. The important application which the abbé thought he could make of this experiment will be ſeen hereafter.

78 *When an inſulated veſſel is electrified, and an inſulated body, ſuch as a ball-electrometer, is ſuſpended within the cavity of the veſſel, the body ſhows no ſigns of electrical attraction or repulſion.*

The experiment by which this principle is to be illuſtrated, is called the *electrical well*, and is thus deſcribed by Mr Cavallo.

79 Electrical well. "Place upon an electric ſtool a metal quart mug, or ſome other conducting body nearly of the ſame form and dimenſion; then tie a ſhort cork-ball electrometer, of the kind repreſented fig. 16. (N), at the end of a ſilk thread proceeding from the ceiling of the room, or from any other proper ſupport, ſo that the electrometer may be ſuſpended within the mug, and no part of it may be above the mouth; this done, electrify the mug, by giving it a ſpark with an excited electric or otherwiſe, and you will ſee that the electrometer, whilſt it remains in that inſulated ſituation, even if it be made to touch the ſides of the mug, is not attracted by it, nor does it acquire any electricity; but if, whilſt it ſtands ſuſpended within the mug, a conductor ſtanding out of the mug be made to communicate with, or only preſented to it, then the electrometer acquires an electricity contrary to that of the mug, and a quantity of it, which is proportionable to the body with which it has been made to communicate; and it is then immediately attracted by the mug.

If, by raiſing the ſilk thread a little, part of the electrometer, i. e. of its linen threads, be lifted juſt above the mouth of the mug, the balls will be immediately attracted; for then, by the action of the electricity of the mug, it will acquire a contrary electricity, by giving to, or receiving the electric power from, the air above the cavity of the mug."

This experiment may be made in greater perfection by employing a globular glaſs veſſel, with a narrow neck juſt ſufficient to admit the electrometer, which ſhould be faſtened to a crooked glaſs rod, ſo that it may be preſented to any part of the cavity. The outſide of the veſſel ſhould be ſmeared with ſome clammy ſubſtance, as ſyrup or treacle, and may be inſulated by placing it on a wine glaſs. The balls preſented to the outſide when the veſſel is electrified, will be repelled, but preſented to any part of the inſide, they will ſhow no ſigns of electricity, unleſs touched with ſome ſubſtance, as a wire, while within the cavity; when, on being taken out, they will repel each other.

This experiment was invented by Dr Franklin, and is called by him the *electrical cup.*

Chap. II. *Of the diverſities exhibited by the electric power in its paſſage from pointed ſurfaces, and from obtuſe ſurfaces.*

80 *When the electric power paſſes between an electrified body and a pointed conductor, a luminous ſtream is produced, attended with a current of air from the point.*

Exper. 1.—Fix a metallic point in the prime conductor, and ſet the machine in motion. No crackling, but rather a hiſſing noiſe, will be heard, and a light will appear as if iſſuing from the point, and on holding the hand near it, a ſtrong blaſt of air will be found to proceed from it. On holding another point at the diſtance of about half an inch from the point in the prime conductor, a ſtream of light will be ſeen paſſing between them, attended with a crackling noiſe. This current of air will be ſufficiently ſtrong to turn any light bodies which are freely ſuſpended, and in this way the following pleaſing experiments may be made.

Exper. 2.—Cut a round flat piece of cork, with the edges very ſmooth, and ſtick a number of ſmall crow quills into the circumference, with the feather ends as repreſented in fig. 23.; paſs a needle through the centre of the cork, and ſuſpend this needle by a ſmall magnet *m*: on holding the cork near the point Plate CLXXXVIII.

(N) Inſtead of the electrometer, there may be uſed any other kind of ſmall conducting body; but that ſeems beſt adapted to ſuch experiments.

point, the current of air will make it move round with great ſwiftneſs.

81 Electrical horſe-race.

Exper. 3.—Let four arms of wire, with their extremities pointed and turned all in the ſame direction, be ſtuck in the circumference of a ſmall circular piece of light wood, ſupported on a pointed wire, as repreſented in fig. 24. On bringing the wires near the point in the conductor, while the machine is in motion, they will move ſwiftly round as before, and in the dark, a beautiful circle of fire will be produced by the light iſſuing from the points. If figures of dogs, horſes, &c. formed of elder pith, be ſtuck on the points, they will appear as if purſuing each other, thus forming what Mr Kinnerſly called the *electrical horſe-race*.

Exper. 4.—Fix eight bells near the edge of a circular board ſupported on four feet, as repreſented fig. 25, having a glaſs pillar *e* in the centre, terminated by a point *g*. On this point place the pointed wires uſed in the laſt experiment, hanging from one of them as *d*, a ſmall glaſs clapper by a ſilken thread; and connecting the apparatus by a chain *h*, proceeding from the prime conductor. On ſetting the machine in motion, the wire will move round, and the clapper ring the bells.

82 Electrical orrery.

Exper. 5.—By this motion of circulating points we may in ſome meaſure imitate the revolutions of the heavenly bodies, forming what is called the *electrical orrery*. Let a ſingle wire, with the extremities pointed and turned as before, be nicely balanced on a point; fix a ſmall glaſs ball over its centre, as *a*, fig. 26, to repreſent the ſun. At one extremity of the wire, let a ſmall wire be ſoldered perpendicularly, and on this balance another ſmall wire with its ends pointed and turned, and having a ſmall pith ball *w* in its centre to repreſent the earth, and a ſmaller ball of the ſame kind at one of the angles for the moon. Let the whole be ſupported upon a glaſs pillar, and be conducted by a chain proceeding from the prime conductor to the wire ſupporting the glaſs ball. Now, when the machine is put in motion, the wires will turn round, ſo that the ball repreſenting the earth will move round the central ball, and the little ball at the angle of the ſmaller wire will at the ſame time revolve about the earth.

83 Gravitation reſiſted by the action of points.

Exper. 6.—The power exerted by electricity upon points, may under ſome circumſtances be made to counteract the power of gravitation. Let an inclined plane be formed of two parallel wires faſtened by their extremities to four pillars of ſolid glaſs, M, N, O, P, fig. 27. fixed in a board ſo that the two at one end ſhall be higher than the other two. Then fix a wire with its ends pointed and turned in the ſame direction, at right angles upon a wire axis. When this axis is laid upon the inclined plane, it will of courſe roll to the bottom, but if, when it has nearly arrived there, the machine be put in motion, the wire will return up the plane, revolving on its axis.

84 The electrified cotton.

Exper. 7.—Take a ſmall lock of cotton, extended in every direction as much as can conveniently be done, and by a linen thread about five or ſix inches long, or by a thread drawn out of the ſame cotton, tie it to the end of the prime conductor; then ſet the machine in motion, and the lock of cotton on being electrified, will immediately ſwell, by repelling its filaments from one another, and will ſtretch itſelf towards the neareſt conductor. In this ſituation let the cylinder be kept in motion, and preſent the end of your finger, or the knob of a wire, towards the lock of cotton, which will then immediately move towards the finger, and endeavour to touch it; but take with the other hand a pointed needle, and preſent its point towards the cotton, a little above the end of the finger, and the cotton will be obſerved immediately to ſhrink upwards, and move towards the prime conductor. Remove the needle, and the cotton will come again towards the finger. Preſent the needle, and the cotton will ſhrink again.

85 *When the electric power paſſes between an electrified body and a conductor whoſe ſurface is obtuſe, a luminous ſpark is produced, attended with an exploſion, and theſe appearances are more or leſs ſtrong in proportion as the ſurfaces are more or leſs obtuſe.*

86 Drawing ſparks.

Exper. 1.—When the prime conductor is ſituated in its proper place, and electrified by whirling the cylinder, if a metallic wire with a ball at its extremity, or the knuckle of a finger, be preſented to the prime conductor, a ſpark will be ſeen to iſſue between them, which will be more vivid, and will be attended with a greater or leſs exploſion, according as the ball is larger. The ſtrongeſt and moſt vivid ſparks are drawn from that end or ſide of the prime conductor, which is fartheſt from the cylinder. The ſparks have the ſame appearance whether they be taken from the poſitive or the negative conductor; they ſometimes appear like a long line of fire reaching from the prime conductor to the oppoſed body, and often (particularly when the ſpark is long, and different conducting ſubſtances in the line of its direction) it will have the appearance of being bent to ſharp angles in different places, exactly reſembling a flaſh of lightning.

87 Figure of the electric ſpark.

The figure of the ſpark varies with the ſuperficial dimenſions of the part from which it is taken. If it be drawn from a ball of two or three inches in diameter, it will have the appearance of a ſtraight line; but if the ball from which it is drawn be much ſmaller, as half an inch in diameter, it will aſſume the zig-zag appearance above mentioned.

We have juſt ſeen that when the electric power paſſes from a point to a point, there are no ſparks, but a luminous ſtream appears; but if the point be obliterated, by being thruſt back ſo as to be on a level with the ſurface of the conductor, by being held between the fingers &c. the ſparks will appear as before.

88 Length of the ſpark.

The length of the ſpark, or the diſtance through the air which it ſtrikes from the conductor, depends on ſeveral circumſtances; as, the length and diameter of the conductor; the termination of the ſurface from which, or to which, the ſpark paſſes; the dimenſions of the cylinder; and the poſition of the conductor.

1. If the conducting body be increaſed in length only, the diſtance of the ſpark will be ſhortened. This fact was very early obſerved by Dr Prieſtley. He found that a ſpark from the end of a wire ſeveral yards in length, and about one fourth of an inch in diameter, was not longer than one taken from a conductor two feet in length, and two inches in diameter. Signior Volta found, that when he connected ſeveral rods, eight feet long, and half an inch in diameter, ſuſpended at the diſtance of eight inches from each other, the ſpark drawn from them was not ſo long as one drawn from a conductor of the ſame length, but of twelve inches diameter.

diameter. Mr Brook of Norwich connected nearly twenty rods of wood covered with tin-foil, near ſeven feet long, and three-fourths of an inch in diameter, at about a foot from each other, ſo that the whole apparatus reſembled a large gridiron, which was ſuſpended from the cieling by glaſs rods. From ſo large an extent of conducting ſurface no ſpark exceeding ſix inches could be drawn; whereas from a conductor eight feet long, and five inches in diameter, ſparks may often be drawn above nine inches long, with the ſame cylinder.

2. If the diameter of the conductor be increaſed in proportion to its length, the ſpark is not ſo long as when it is ſhortened, while the diameter is increaſed. A conductor twelve feet long, and eight inches in diameter, does not yield a ſpark above half the length that may be drawn from a conductor of the ſame diameter, only ſix feet long.

3. The ſpark will ſtrike to a greater diſtance, according as the cylinder is ſmaller in proportion to the conductor. A much longer and more violent ſpark was drawn from Mr Brook's gridiron conductor with a cylinder only four inches in diameter than from a conductor five feet long, and ſix inches in diameter, with the ſame cylinder.

4. The length of the ſpark is greater from a ball of moderate dimenſions than from the ſurface of the prime conductor.

5. The ſpark will be longer when the conductor is placed parallel to the cylinder, than when it is at right angles with the cylinder.

89 Sound of the ſpark. The *ſound* of the ſpark varies according as the ſurfaces between which it ſtrikes are more or leſs obtuſe. It is louder when the ſpark is taken from the prime conductor, than when taken from a ball annexed to it; and it is loudeſt of all when the ſpark ſtrikes from one flat ſurface to another: a ſtraight ſpark is always louder than one of the zig-zag appearance. If the ſpark be made to paſs from one end of a glaſs tube (cloſed at both ends and very dry) to the other, the ſound is entirely huſhed.

90 Force of the ſpark. When the ſpark is received by the knuckle it produces a ſenſation which is more or leſs painful. It is more pungent when received from the prime conductor than from a ball attached to it. The ſpark produces a more painful ſenſation in proportion as it is ſhorter.

91 Light of the ſpark. The moſt remarkable circumſtance attending the electric ſpark is the light (o) produced in its paſſage through the air. The ſparks which uſually paſs between the rubber of the negative conductor, through the cylinder to the points of the poſitive conductor, are of a beautiful light blue colour; but when the ſpark paſſes between the prime conductor and a ball of the diameter of an inch, its edges are purpliſh, and from theſe diverge ſeveral ramifications of a purple or indigo colour. If the balls between which the ſpark paſſes are not more than half an inch diſtance from each other, a continued ſtream of the moſt brilliant light will be produced, attended with a whizzing noiſe. If the diſtance of the balls from each other be increaſed, ſparks equally brilliant will be produced; but their ſucceſſion will be leſs quick, and no continued ſtream will appear.

The light emitted from electrified conductors is more copious and brilliant in proportion as their ſurfaces are more extended. If a perſon ſtanding on an inſulating ſtool, and connected with the prime conductor of a machine in motion, hold a flat plate of metal, as a pewter plate, while another perſon ſtanding on the floor holds another plate, large flaſhes of vivid light will appear between the plates, ſo as to illuminate a dark room.

92 Peculiar odour attending the ſpark. Soon after the cylinder is ſet in motion, and ſparks begin to iſſue, a peculiar odour may be perceived; and if the machine acts well, this is very powerful. It is difficult to deſcribe this odour, but it ſeems to reſemble that of phoſphorus.

CHAP. III. *Of charging and diſcharging the Leyden Phial; with directions for the conſtruction of Jars and Batteries.*

93 *The electric power is communicated to electrics with difficulty, unleſs their ſurfaces be covered with ſome conducting ſubſtance; but it may be accumulated on them in a much greater degree than on conductors.*

94 Dancing balls. *Exper.* 1.—Take a common tumbler or glaſs jar, and having placed a braſs ball in one of the holes of the prime conductor, ſet the machine in motion, and let the balls touch the inſide of the tumbler; while the ball touches only one point, no more of the ſurface of the glaſs will be electrified, but by moving the tumblers about ſo as to make the ball touch many points ſucceſſively, all theſe points will be electrified, as will appear by turning down the tumbler over a number of pith or cork balls placed on a table. Theſe balls will immediately begin to fly about, thus ſhowing the electric attraction and repulſion illuſtrated in (61). This experiment is commonly called the experiment of the *dancing balls*, and is repreſented at fig. 28. Plate CLXXXVIII.

95 Conſtruction of the Leyden phial. *Exper.* 2.—Let a glaſs jar, either cylindrical, ſuch as is repreſented at fig. 12. Plate CLXXXVII. or with as wide a mouth as poſſible, be covered on both its inſide and outſide ſurfaces to within two inches of the top, with tin foil faſtened on by means of gum water. The jar is then ſaid to be *coated.* Fit to the mouth of the jar a piece of baked wood, through the centre of which paſs a wire, whoſe lower extremity is terminated by a number of other wires, which muſt be made to touch the inſide coating, while its upper extremity projects an inch or two above the mouth of the jar, and terminates in a metallic ball *a*. This ball ſhould be perforated ſo as to receive a wire ſupporting a quadrant electrometer.

96 Method of charging and diſcharging it. The jar being thus prepared, let the knob *a* communicate with the prime conductor, and let it remain while the cylinder is in motion till the ball *c* of the electrometer ſtands nearly horizontal; the jar is then ſaid to be *charged.* It may be removed from the conductor

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(o) The firſt perſon who ſeems to have obſerved the electric light was Otto Guericke. He appears indeed only to have had a glimpſe of it; and the firſt who perceived it in any great degree was Dr Wall, on rubbing a pretty large piece of amber. *Vid. Philoſ. Tranſ. abridged*, vol. ii.

ductor without any effect being produced ſo long as the inſide coating has no communication with the outſide.

Let there be provided a curved braſs rod, terminating at each end in a knob, and furniſhed with a glaſs handle, ſuch as D *e f*; if now one of the knobs, as *e*, be made to approach the ball *a* of the jar, while the other knob *f* touches the outſide coating, a conſiderable exploſion will take place, and the jar will loſe its electricity, as will appear by the ball of the electrometer falling into a perpendicular ſituation.

The jar is then ſaid to be *diſcharged*, and the rod *def* is called a *diſcharging rod*.

A jar or phial of glaſs thus conſtructed is, for a reaſon which will preſently appear, called a *Leyden jar* or *phial*.

In this experiment, the jar is not charged to its utmoſt height. If, inſtead of ſtopping when the index of the quadrant is nearly at right angles, we perſiſt in charging, there will ſoon appear ſeveral luminous ſtreams paſſing from the prime conductor acroſs the cylinder to the cuſhion. Preſently an exploſion will take place from the phial, and this is called its *ſpontaneous diſcharge*. If the phial is not very ſtrong, it will probably either be broken, or on examination will be found perforated in ſome part. If the glaſs be very thin, a ſpontaneous diſcharge will ſoon take place, attended with a harſh craſhing noiſe, and the phial will certainly be cracked. A ſpontaneous diſcharge happens much more readily when the neck of the phial is very ſmall, and conſequently the wire comes very near the uncoated part of the glaſs.

If the uncoated part of the glaſs be moiſt or duſty, the jar will not receive a charge; ſo that it is neceſſary to be very careful in cleaning the jar before uſing it. When the uncoated part is made very hot, the ſpontaneous diſcharge is much accelerated.

The appearance of the uncoated part of the jar, when the diſcharge is made in the dark, is very curious. A great number of luminous ſtreams will be ſeen pouring over the edge of the jar from the inſide to the outſide.

The force of the exploſion depends very much on the termination of the extremity of the *diſcharging rod*. If this be terminated by a large ball, the noiſe will be much greater than when the ball is ſmall; if it be terminated by a ſmall obtuſe ſurface, a hiſſing noiſe is heard before the exploſion, and this is faint. But if the rod terminate in a point, no exploſion will take place, but the jar will be ſilently diſcharged.

In the above experiment the jar is charged poſitively, it having been in contact with the poſitive conductor; but if it be connected with the negative conductor, the jar will be charged negatively. This will be more fully illuſtrated by and by.

As the accumulation of the electric power by means of coated jars forms one of the moſt important diſcoveries which have been made in this ſcience, we ſhall here relate the method in which the diſcovery was made.

97
Diſcovery of the Leyden phial by M. Van Kleiſt.

This diſcovery was accidental, and was the reſult of an experiment made in the end of the year 1745 by M. Van Kleiſt, dean of the cathedral in Cammin, who ſent the following account of it to Dr Leiberkuhn at Berlin.

When a nail or a piece of thick braſs-wire, &c. is put into a ſmall apothecary's phial, and electrified, remarkable effects follow; but the phial muſt be very dry or warm. I commonly rub it once before hand with a finger, on which I put ſome pounded chalk. If a little mercury, or a few drops of ſpirits of wine, be put into it, the experiment ſucceeds the better. As ſoon as this phial and nail are removed from the electrifying glaſs, or the prime conductor to which it has been expoſed, is taken away, is taken away, it throws out a pencil of flame ſo long, that with this burning machine in my hand, I have taken above ſixty ſteps in walking about my room. When it is electiſied ſtrongly, I can take it into another room, and there fire ſpirits of wine with it. If, while it is electrifying, I put my finger, or a piece of gold, which I hold in my hand, to the nail, I receive a ſhock which ſtuns my arms and ſhoulders.

A tin tube, or a man placed upon electrics, is electrified much ſtronger by this means than in the common way. When I preſent this phial and nail to a tin tube, which I have, fifteen feet long, nothing but experience can make a perſon believe how ſtrongly it is electrified. Two thin glaſſes have been broken by the ſhock of it. It appears to me extraordinary, that when this phial and nail are in contact with either conducting or non-conducting matter, the ſtrong ſhock does not follow. I have cemented it to wood, metal, glaſs, ſealing-wax, &c. when I have electrified without any great effect.

M. Van Kleiſt communicated this experiment to ſeveral of his acquaintances, but they all for ſome time failed in their attempts to repeat it.

98
Experiment by Mr Cuneus.

An experiment of a ſimilar kind was ſoon after made at Leyden by Mr Cuneus. Making an attempt to communicate the electric power to water, contained in a phial, in which was a nail, happening to hold his glaſs in one hand, while he diſengaged it from the prime conductor with the other, when he imagined that the water had received as much electricity as it was capable of acquiring, he was ſurpriſed with a ſudden ſhock in his arms and breaſt, which he had not in the leaſt expected.

This experiment was afterwards repeated in the preſence of M. M. Allamand and Muſchenbroeck with ſimilar reſults; and as it was at Leyden that the experiment was made with the greateſt ſucceſs, and afterwards improved, it obtained the name of the Leyden experiment, and a phial ſo conſtructed as to exhibit ſimilar phenomena, has been ever ſince called a Leyden phial.

99
Views which led to this diſcovery.

Indeed the philoſophers of Leyden ſeem to have ſome merit in this diſcovery, which with them does not appear to have been merely accidental. The views which are ſaid to have led to it were as follow. Profeſſor Muſchenbroeck and his friends, obſerving that electiſied bodies, expoſed to the common atmoſphere, which is always replete with conducting particles of various kinds, ſoon loſt their electricity, and were capable of retaining but a ſmall quantity of it, imagined, that were the electric bodies terminated on all ſides by original electrics, they might be capable of receiving a ſtronger power, and retaining it a longer time. Glaſs being the moſt convenient electric for this purpoſe, and water the moſt convenient non-electric, they firſt made theſe experiments with water in cloſe bottles *.

100
Progreſſive improvement of the Leyden phial.

For a long time water and ſpirit of wine were the only conductors employed in this experiment; but it was

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* *Prieſtley, Hiſt. Elect.*

was ſoon found by Dr Watſon, that the experiment ſucceeded better when the outſide of the glaſs was coated with ſome metallic leaf, as ſheet-lead, or tin-foil, while the phial contained ſome water within; and after this there was a natural tranſition to the uſe of an internal as well as external metallic coating, and thus the Leyden phial was completed in its preſent form (P).

101
Electrical battery deſcribed.

A number of coated jars having their internal coatings connected together by metallic wires, conſtitute what is called a *battery*. Fig. 14. repreſents an electrical battery of the moſt approved form, containing nine jars. The bottom of the box is covered with tin-foil to connect the exterior coatings; the inſide coatings of the jars are connected by the wires *a b c*, *d e f*, *g h i*, which meet in the large ball A; a ball B proceeds from the inſide, by which the circuit may be conveniently completed. In one ſide of the box, near the bottom, is a hole through which a braſs hook paſſes, and which communicates with the metallic lining of the box, and conſequently with the outſide coating of the jars. To this a wire or chain is occaſionally connected when a diſchatge is made; and for the more convenient making of this diſcharge, a ball and wire, B, proceed to a convenient diſtance from the centre of the ball A. When the whole force of the battery is not required, one, two, or three jars may be removed, only by preſſing down the wires belonging to them, until their extremities can ſlip out of their reſpectives holes in the braſs ball, and then turning them into ſuch a poſture that they cannot have any communication with the battery. The number of jars repreſented in this figure is rather ſmall for ſome purpoſes; but it is better to join two or three ſmall batteries, rather than have a ſingle large one, which is inconvenient on account of its weight and unwieldineſs.

102
Directions for the conſtruction of jars and batteries.

As coated jars form one of the moſt expenſive parts of an electrical apparatus, it is of conſequence that the electrician ſhould himſelf be able to adjuſt them for experiment, and repair the coating, &c. when injured. We ſhall therefore give particular directions for the preparation of jars and batteries. The circumſtances neceſſary to be attended to, reſpect principally the form of the coated electric, the ſubſtance employed as an electric, and the conductor employed as a coating.

103
Form of jars, &c.

For moſt experiments the beſt form is that of a cylindrical jar, in which the mouth is large enough to admit the introduction of the hand. A phial of this form is much more eaſily coated, cleaned, or repaired, than one of any other form. Mr Cuthbertſon uſed to make his jars *entirely* cylindrical, but now heis of opinion that it is better to have the mouth a little contracted, and he has of late always made his jars of this latter form. For illuſtrating the theory of coated electrics, as we ſhall ſee hereafter, plates are the moſt convenient, and they are alſo uſeful in ſome experiments. Dr Robiſon prefers bottles of a globular form to any other, and he commonly employed the balloons uſed in diſtillation, which he ſays make excellent jars. The bottles employed for holding mineral acids alſo make very good jars, but they are rather inferior to the balloons, as having very thick bottoms. For ordinary purpoſes, where a glaſs-houſe is at a great diſtance, common green glaſs bottles or apothecary's phials with the mouths as wide as poſſible, will anſwer very well.

104
Electrics employed.

With reſpect to the electric employed for this purpoſe, glaſs is to be preferred on many accounts, and of this the beſt kind, as flint or cryſtal: but the expence here becomes a very conſiderable object, eſpecially as the jars of a battery are very apt to break by reaſon of the inequality of their ſtrength; for it ſhould ſeem that the force of the electric power in a battery is equally diſtributed among all the bottles, without any regard to their capacities of receiving a charge ſingly conſidered. Thus if we expreſs the quantity of charge which one jar can eaſily receive, by the number 10, we ought not to connect ſuch a jar in a battery with one whoſe capacity is only 8; becauſe the whole force of electricity expreſſed by 10 will be directed alſo againſt that whoſe capacity is only 8, ſo that the latter will be in danger of being broken. It will be proper, therefore, to compare the bottles with one another in this reſpect before putting them together in a battery. Beſides the conſideration of the abſolute capacity which each bottle has of receiving a charge, the time which is taken up in charging it muſt alſo be attended to, and the jars of a battery ought to be as equal as poſſible in this reſpect as well as the former. The thinner a glaſs is, the more readily it receives a charge, and *vice verſa*; but it does not follow from thence, as was formerly imagined, that on account of its thinneſs it is capable of containing a greater charge than a thicker one. The reverſe is actually the caſe; and though a thick glaſs cannot be charged in ſuch a ſhort time as a thin one, it is nevertheleſs capable of containing a greater degree of electric power. In fact, if the glaſs be thinner than one-eighth of an inch, the phial will not bear any conſiderable charge. If the thickneſs of the glaſs be very great, no charge can indeed be given it; but experiments have not yet determined how great the thickneſs muſt be which will prevent any charge. Indeed it is obſerved, that though a thick glaſs cannot be charged by a weak electrical machine, it may be ſo by a more powerful one, whence it ſeems reaſonable to ſuppoſe that there is no real limit of this kind; but that if a machine could be made ſufficiently powerful, glaſſes of any thickneſs might be charged.

Glaſs is attended with one conſiderable inconvenience; that it is very apt to attract moiſture, and therefore the jars acquire perpetual care in wiping before they are uſed; and this, when a large battery is employed, becomes a very troubleſome operation. It is the uncoated part of the jar which is injured by the moiſture, for it is found, that if the coating be moiſt, the jar is more eaſily and more completely charged.

Electricians

(P) Dr Watſon was indebted for the hint of a *metallic* coating to Dr Bevis, who was alſo the firſt electrician that employed a *plate* of glaſs coated on both ſides in performing the experiments with coated electrics. Hence the coated plate is often called, eſpecially by the continental electricians, Bevis's plate, or ſquare, *le carreau de Bevis*.

Electricians have often endeavoured to find ſome other electric which might anſwer better than glaſs for this purpoſe, at leaſt be cheaper; but except Father Beccaria's method, which may be uſed very well, no remarkable diſcovery has been made relating to this point.

105 Subſtitute for glaſs by Beccaria.

He took equal quantities of very pure colophonium and powder of marble ſifted exceeding fine, and kept them in a hot place a conſiderable time, where they became perfectly free from moiſture; he then mixed them, and melted the compoſition in a proper veſſel over the fire, and when melted, poured it upon a table, upon which he had previouſly ſtuck a piece of tin-foil, within two or three inches of the edge of the table. This done, he endeavoured with a hot iron to ſpread the mixture as equally as poſſible, and to the thickneſs of one-tenth of an inch all over the table; he afterwards coated it with another piece of tin-foil, reaching within about two inches of the edge of the mixture; in ſhort he coated a plate of this mixture as he would a plate of glaſs. This coated plate ſeems, from what he ſays, to have had a greater power than a glaſs plate of the ſame dimenſions: even when the weather was not very dry, and if it is not liable to be eaſily broken by a ſpontaneous diſcharge, it may be conveniently employed in place of glaſs; for it does not very readily attract moiſture, and conſequently may hold a charge better and longer than glaſs, beſides when broken, it may be again repaired by means of a hot iron, whereas a broken plate or veſſel of glaſs can ſeldom be employed again.

106 Talc a very good electric for coating.

Talc, or Muſcovy glaſs, is one of the moſt convenient electrics for the purpoſes of coating. It is not very apt to contract moiſture, and will retain a charge for a very conſiderable time.

A very convenient portable phial may be conſtructed of ſealing wax in the following manner: Procure a phial made of tin-plate, or white-iron (as it is called in Scotland), with a long neck; cover the outſide of this phial with ſealing wax as far as the neck, and coat the ſealing wax to within a little of the neck with tin-foil. In this phial it is evident that the ſealing wax is the electric, of which the tin-foil forms the outer and the tin-plate the inner coating.

107 Method of coating plates and jars.

When plates or jars having a ſufficiently large opening are to be coated, the beſt method is to coat them with tin-foil on both ſides, which may be fixed upon the glaſs with varniſh, gum water, bees wax, &c.; but in caſe the jars have not an aperture wide enough to admit the tin-foil, and an inſtrument to adapt it to the ſurface of the glaſs, braſs filings, ſuch as are ſold by the pin-makers, may be advantageouſly uſed; and theſe may be ſtuck on with gum water, bees wax, &c. but not with varniſh, for this is apt to be ſet on fire by the diſcharge. Care muſt be taken that the coating do not come very near the mouth of the jar, for that will cauſe the jar to diſcharge itſelf. If the coating is about two inches below the top, it will in general do very well; but there are ſome kinds of glaſs, eſpecially tinged glaſs, that when coated and charged have the property of diſcharging themſelves more eaſily than others, even when the coating is five or ſix inches below the edge.

It is much more difficult to coat veſſels of a globular form than plates or cylindrical jars; but the former may be coated with tolerable eaſe by attending to the method of cutting the tin-foil. This ſhould be cut into the form of guſſets as in covering a globe or in making a balloon; and they ſhould be paſted on, ſo as to overlap each other about half an inch. After having coated the ſides of a balloon in this manner, the bottom is to be covered with a circular piece of tin-foil. The thinner the foil, the better it is adapted for the inſide coating; and it may readily be applied by firſt paſting it upon paper, and then paſting either the paper or the foil next the glaſs.

In coating plates of glaſs it is better to cut the tin-foil into circular pieces, as it is found that a circular ſpace is capable of giving as great a charge to the glaſs, as a ſquare coating of the ſame breadth, and a ſpontaneous diſcharge does not ſo readily take place from the circular edge, as from the edges of a ſquare coating.

108 Mr Brooke's mode of coating.

Mr Brooke diſcovered, that when jars were coated with tin-foil firſt paſted upon paper, they were rendered much leſs liable to be broken by the diſcharge. As the trials which led to this diſcovery afford a uſeful leſſon to the young electrician, we ſhall relate them in his own words.

"In making electrical experiments, and in particular thoſe in which the Leyden phial is concerned, a method of preſerving the bottles or jars from being ſtruck through by the electric power, is very deſirable; but I do not know that it has hitherto been accompliſhed. The number of them that have been deſtroyed in many of my experiments, have led me to various conjectures to preſerve them: at the ſame time I have been obliged to make uſe of bottles inſtead of open-mouthed jars. And as coating the former withinſide is very troubleſome, it has put me on thinking of ſome method more eaſy, quicker, and equally firm and good, as with tin-foil. With reſpect to the new method of coating, I failed; though ſomething elſe preſented itſelf rather in favour of the former: therefore, introducing the proceſs here will not be of very great uſe; unleſs in ſaving another the trouble of making uſe of the ſame method, or giving a hint towards the former ſo as to ſucceed with certainty. My aim was to find ſomething that ſhould be quick and clean, and not eaſy to come off with the rubbing of wires againſt it, and yet a good conductor. My firſt eſſay was with a cement of pitch, roſin, and wax, melted together; into which, to make it a good conductor, I put a large proportion of finely ſifted braſs filings. When this mixture was cold, I put broken pieces of it into the bottle, and warmed the bottle till it was hot enough to melt the cement in it ſo as to run, and cover the bottle withinſide; then I coated the outſide with tin-foil, as is commonly done, and now it was fit for uſe or ready to be charged, to which I next proceeded; and I believe I had not made more than four or five turns of the winch, before it ſpontaneouſly ſtruck through the glaſs with a very ſmall charge. I then took off the outſide coating, and ſtopped the fracture with ſome of my common cement, after which I put the coating on again; and in as little time as before, it was ſtruck through again in a different place; and thus I did with this bottle five or ſix times; ſometimes it ſtruck through the glaſs in four different places. This made me conſider what it might be that facilitated the ſpontaneous ſtriking through the glaſs, and likewiſe what might retard it. I had, long before,

before, thought that jars or bottles appeared to be ſtruck through with a much leſs charge, juſt after their being coated, or before they were dry, than when they had been coated long enough for the moiſture to be evaporated from the paſte, with which I moſtly lay on the tin-foil, and could only conſider the dry paſte as a kind of mediator between the tin-foil and the glaſs, or in other words, that the moiſture in the paſte was a better conductor and more in actual contact with the glaſs than the paſte itſelf when dry. And the coating the bottles with the heated cement, though long afterward, did not alter my former idea; for it appeared as if the hot cement, with the conducting ſubſtance in it, might be ſtill more in actual contact with the glaſs than the moiſture in the paſte. On theſe probabilities I had to conſider what might act as a kind of mediator more effectually than the dry paſte, between the glaſs and the tin-foil. It occurred, that common writing paper, as being neither a good conductor nor inſulator, might be ſerviceable by being firſt paſted ſmoothly to the tin-foil, and left to dry. The paper then being paſted on one ſide, having the tin-foil on the other, I put them on the glaſs together with the tin-foil outward, and rubbed them down ſmooth. This ſucceeded ſo well that I have never ſince had any ſtruck through that were thus done, either common phials or large bottles, which contain near three gallons each, though ſome of the latter have ſtood in the battery in common uſe with the others for a long time. And as I have never had one ſtruck through that has been prepared in this way, I am much leſs able at preſent to tell how great a charge they will bear before they are ſtruck through, or whether they will be ſtruck through at all *."

The mineral acids ſerve very well for an inſide coating to jars; but their uſe is attended with ſome riſk, from their corroſive quality.

109 Directions for fixing the wire, &c.

The wire through which the charge is made, ſhould not be leſs than the fourth of an inch in diameter; it ſhould be terminated by a metallic ball, at leaſt one inch in diameſer.

If the phials be intended to be frequently removed from one place to another, the charging wire muſt be faſtened ſo as to be always ſteady in the centre of the phial. For this purpoſe, ſome employ a piece of wood, to fit the mouth of the phial like a lid, but the length of inſulation which ſeparates the coating from the phial is thus diminiſhed, and conſequently, as we ſhall ſee hereafter, the phial is more liable to a gradual ſpontaneous diſcharge, ſo that it is much more difficult to charge it. The wire is beſt faſtened below the edge of the inner coating, and in this way Mr Cuthbertſon conſtructs his jars, the mouth being left entirely open.

When the phial is not to be removed from the ſituation in whch it is charged, the wire may be faſtened to the conductor.

110 Conſtruction of batteries.

Batteries may be formed either of plates or jars. A very compendious battery may be made in the following manner. Select a number of plates of the beſt crown glaſs that are very flat and thin; coat them on each ſide with a circular piece of tin-foil paſted in the middle of the plate, ſo as to leave a margin ſufficiently wide to prevent a ſpontaneous diſcharge; let a narrow ſlip of tin-foil paſs from the circumference of the coating on each ſide, and lay the plates upon each other ſo that theſe ſlips may coincide. Let the ſlips be connected at their ends by a wire which touches them all; then if one of theſe ſlips be connected with the prime conductor, and the other with the ground, the whole may be charged or diſcharged together. If we wiſh to have a number of theſe plates connected ſo as to form a perpetual battery, they may be cemented by covering the tin-coated margins with melted pitch, and preſſing the plates down on each other while the pitch is ſoft till the coatings touch each other. But if we deſire to make uſe only of a few of the plates at a time, and to vary their number, they may be placed upon their edges in an open frame; and when we wiſh to make a break in the chain of plates, this may eaſily be done by placing one of them at right angles to the reſt.

A very convenient battery may be formed in this way with coated plates of Muſcovy glaſs; but great caution is neceſſary in the uſe of ſuch plates, as they are very eaſily broken by a ſpontaneous diſcharge, and it is not eaſy to diſcover where the crack has happened.

111 Mr Brooke's mode of conſtructing his batteries.

Mr Brooke of Norwich, conſtructed his batteries, which appear to have been very powerful, of green glaſs bottles. Some of them, like that repreſented in the figure, had only nine of theſe bottles; but when a greater power was wanted, more were added. Jars would have been preferred to bottles, on account of their being more eaſily coated by reaſon of their wide mouths; but being leſs eaſily procured, he was content to put up with this inconvenience. The mean ſize of theſe bottles was about eight inches in diameter; they were coated 10 inches high, and made of the thickeſt and ſtrongeſt glaſs that could be procured, weighing from five pounds and a half to ſeven pounds each. In the conſtruction of a battery of 27 bottles, he diſpoſed of them in three rows; nine of the ſtouteſt and beſt compoſing the firſt row, nine of the next in ſtrength being diſpoſed in the ſecond, and the third containing the nine weakeſt. All of theſe were of green glaſs, but not of the ſame kind. Some of thoſe which ſtood in the foremoſt row, were compoſed of a kind very much like that of which Frontigniac wine bottles are made; and our author remarks, that this kind of glaſs ſeems to be by much the beſt, as being both harder and ſtronger, and leſs liable to break by a high charge. The ſecond and third rows of the battery conſiſted of bottles whoſe diameter was from ſix and a half to ten inches, and which were coated from eight and a half to eleven inches high; none of their mouths being larger than an inch and a half, nor leſs than three quarters of an inch.

All the bottles of this battery, as well as the ſingle ones which he commonly made uſe of in his experiments, were coated both on the inſide and outſide with ſlips of tin-foil from three-eighths to three-fourths of an inch wide, laid on with paſte of flour and water, at the diſtance of about a ſlip between each.

112 Mr Morgan's rules for the conſtruction of batteries.

Mr G. Morgan lays down the following requiſites as eſſential in the conſtruction of a battery.

1. Its connecting wires ſhould be perfectly free from all points and edges.

2. The connecting wires ſhould be eaſily moveable, ſo that when accident has leſſened the number of phials, the

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* *Brooke's Miſcellaneous Experiments and Obſervations.*

the number of wires may be reduced ſo as to correſpond with the remaining quantity of glaſs.

3. The phials ſhould not be crowded; for in ſuch a caſe, if neceſſity ſhould oblige us to employ phials of different heights or ſizes, the tin-foil of the higher ones, being in contact with the uncoated glaſs of the lower ones, the inſulation will thus be rendered leſs complete.

4. The ſize of the phials ſhould not be large; for though an increaſe of magnitude leſſens the trouble of cleaning, it at the ſame time increaſes the expence of repairing damages which frequently occur.

5. The ſeveral wires ſhould be fixed very ſteadily, or in ſuch a manner as not to admit of any ſhaking.

6. The battery ſhould take up the leaſt poſſible room; for as it increaſes in ſize, ſo is the probability increaſed of its being expoſed to the influence of ſurrounding conductors.

113
Origin of the electrical battery.

The firſt electrical battery appears to have been conſtructed in the year 1746 by Mr Gralath, a German. Dr Franklin conſtructed a battery conſiſting of eleven plates of common window glaſs, and with this he made moſt of the experiments which will be mentioned hereafter. The conſtruction of the battery was greatly improved by Dr Prieſtley, who formed them of conſiderable ſize and power. In his hiſtory he deſcribes and figures one conſiſting of ſixty-four jars, each ten inches high, and two inches and a half in diameter, and the whole battery containing 32 ſquare feet of coated ſurface.

114
Van Marum's battery.

But the moſt complete electrical batteries are thoſe made by Mr Cuthbertſon for Teyler's muſeum at Haarlem. Of theſe batteries there are two, differing in their magnitude and mode of conſtruction, but allowed to be equally perfect. The firſt was completed in the year 1784, and is compoſed of 135 jars in nine boxes, which may be uſed ſeparately or combined, as the nature of the experiment requires. Each box is a ſeparate battery of itſelf; and the deſcription of one box will be ſufficient for explaining its conſtruction and uſe. Each box contains 15 jars; each jar is 11 inches high, and ſix inches in diameter, contracted at the mouth to four inches, and coated ſo as to contain 140 ſquare inches; and thus the whole battery will contain about 132 ſquare feet of coated ſurface. Each box is divided into 15 partitions, five of which are in the length and three in the breadth; the height of the ſides of the box being ſomewhat lower than the coating of the jars, as are alſo the partitions in which they ſtand. The lid of the box is made without hinges, for the convenience of releaſing it from the box, that it may be removed while experiments are performed. It is taken off by lifting it upwards. The outſide coatings of the jars are connected by means of croſs wires paſſing under the bottom of each jar; and thoſe on the inſide by means of a braſs frame, bearing 15 braſs balls, fixed upon the frame above the centre of each jar. All theſe bells, excepting the four at the corners, have wires ſcrewed to them and hanging downwards into the inſide of each jar; but the wires of the four corner jars are ſcrewed to a foot, which is cemented to the bottom of each in the inſide. Upon theſe wires the whole frame reſts, and is kept in its proper poſition. The four corner balls have holes, which receive the ends of the wires, and terminate at a proper height from the jars. By this contrivance the inſide connecting frame may at any time be eaſily removed. It is according to the above conſtruction that Mr Cuthbertſon forms his preſent batteries, excepting that he has increaſed the ſize of the jars, ſo as to make one battery contain about 17 ſquare feet; and he engages to prove by experiment, that the batteries of his conſtruction are far ſuperior to any others. Teyler's ſecond grand battery was finiſhed by Mr Cuthbertſon in 1789. This is the largeſt and moſt complete battery that was ever made. It conſiſts of 100 jars of the ſame ſhape with that of thoſe already deſcribed, only that they are ſo enlarged in ſize, that each of them contains 5½ ſquare feet of coated ſurface, inſtead of 140 inches, and the whole battery contains 550 ſquare feet of coating; and for conveniency, it is put into four ſeparate caſes, each containing 25 jars in the form of a ſquare, five on each ſide. The boxes are lined with lead on the inſide for forming the outſide communication; each jar has a perpendicular ſtand reſting upon its bottom, and ſupported from falling ſideways by three ſtays on the inſide. Upon the top is ſcrewed a three-inch braſs globe, from which proceeds a braſs tube about one inch in diameter, to a large braſs globe, ſupported by the middle jar at a proper height, ſo as to keep the inſide communication properly arranged.

115
Method of repairing cracked jars.

Various expedients have been thought of to repair jars when cracked, and enable them to bear another charge, but they ſeem to have been attended with very little ſucceſs. Mr Brooke found that when any of his bottles was broken by the diſcharge, it might be conveniently mended and made ſerviceable in the following manner. "Take of Spaniſh white, eight ounces; heat it very hot in an iron ladle, to evaporate all the moiſture; and when cool ſift it through a lawn ſieve; and three ounces of pitch, three quarters of an ounce of roſin, and half an ounce of bees wax; heat them all together over a gentle fire, ſtirring the whole frequently for near an hour; then take it off the fire, and continue the ſtirring till it is cold and fit for uſe." The bottles cemented with this compoſition, however, were not judged to be ſufficiently ſtrong to ſtand in their original place, but were removed to the ſecond or third row, as it was apprehended they could beſt ſuſtain the charge.

116
Of the diſcharging rod.

In relating the experiment of charging and diſcharging a Leyden phial, we have briefly deſcribed the *diſcharging rod*. Diſcharging rods are made of various forms and dimenſions; fig. 13. repreſents one of the moſt common forms. It is convenient that the legs ſhould move upon a hinge, ſo that the balls may be placed at a greater or leſs diſtance as occaſion may require; the extremities of the legs ſhould terminate in points, and the balls be made to ſcrew on and off at pleaſure.

117
Mr Henly's univerſal diſcharger.

Fig. 29. repreſents Mr Henly's univerſal diſcharger; an inſtrument of very extenſive uſe in forming communications between jars, or directing the ſhock through any particular ſubſtance. AB is a flat board fifteen inches long, four broad, and one thick, and forming the baſis of the inſtrument. DC are two glaſs pillars cemented in two holes upon the board AB, and furniſhed at their tops with braſs caps; each of which has a turning joint, and ſupports a ſpring tube, through which the wires EF and ET ſlide. Each of theſe caps is compoſed of three pieces of braſs, connected with each other in ſuch a manner, that the wire EF, beſides its

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its ſliding through the ſocket, has two other motions, viz. a horizontal one, and a vertical one. Each of the wires is furniſhed with an open ring at one end, and at the other has a braſs ball; which, by a ſhort ſpring ſocket, is ſlipped upon its pointed extremity, and may be removed from it at pleaſure. HG is a circular piece of wood five inches diameter, having a ſlip of ivory inlaid on its ſurface, and furniſhed with a ſtrong cylindrical foot, which fits the cavity of the ſocket I. This ſocket is fixed in the middle of the bottom board, and has a ſcrew at K; by which the foot of the circular board is made faſt at any required height.

Fig. 30. is a ſmall preſs belonging to this inſtrument. It conſiſts of two oblong pieces of wood, which are forced together by the two ſcrews, *a*, *a*. The lower end has a circular foot equal to that of the circular table H. When this preſs is to be uſed, it muſt be fixed into the ſocket I, in place of the circular board HG; which in that caſe is to be removed.

118 Mr Morgan's rules for conſtructing a diſcharging rod.

Mr G. Morgan gives the following rules for the conſtruction and uſe of diſcharging inſtruments.

1. They ſhould be conſtructed ſo as to allow no other paſſage to the electric power, than that of the intended circuit.

2. The conducting wires of the inſtrument ſhould be made to come into contact with the inner ſurface of the coated electric as ſpeedily as poſſible; for when approached gradually part of the charge is taken off previous to the exploſion, the power of which is thus greatly diminiſhed.

3. The operator ſhould not be within the atmoſphere of the conductor at the time of making the diſcharge.

4. The diſcharging inſtrument and the inſide of the charged ſurface ſhould be ſeparated as rapidly as they were connected.

119 His diſcharging rod.

On theſe principles the inſtrument employed by Mr Morgan, in his experiments on the conducting power of various ſubſtances, is conſtructed, and is thus deſcribed by him.

A and B, fig. 31. are two braſs wheels, whoſe diameter is four or five inches; they are connected by an axis, which is made to turn eaſily in a collar, fixed upon the glaſs ſtem DM. The wires DC, and EF, are ſcrewed into the circumference of the wheels, but on ſides directly oppoſite to each other. The length of theſe wires is regulated by the diſtances at which the diſcharging rod is fixed from the conducting body, and their direction is perpendicular to the axis of the wheels. Two other wires are to be fixed perpendicularly to the planes of the wheels, to the circumference of which they are ſcrewed as nearly as poſſible, but at oppoſite points, ſo that they may ſtrike objects lying in the ſame line, parallel to the axis at the diſtance of half a revolution from each other. The length of theſe laſt wires is regulated by the diſtances at which they join the metallic or other connection that is formed with the outſide of the coated phial.

The mode of uſing this diſcharging rod is as follows. When C is brought into contact with the conductor, it receives the electric power, and conveys it through G into the outſide of the coated ſurface. The motion of C is not ſtopped by the contact, but the continuance of it brings E into the ſame contact by which the reſidue of the jar is conveyed through K to the outſide. The glaſs ſtem ſhould penetrate deeply into each of the caps, for the whole apparatus will be otherwiſe looſened and put out of order, by the neceſſary rapidity of the motion and the conquaſſation of parts attending it.

If C, in its circumvolutions, ſtrike againſt an immoveable body in connexion with the conductor, it is frequently ſtopped, and then its ball is injured, or a change unfavourable to the accuracy of the experiment takes place.

To prevent theſe inconveniences, C, fig. 32. ſtrikes the ball A which is connected with the braſs tube that penetrates into the conducting ſubſtance, with an elaſtic wire bent into the form of a ſpring. The points and edges of this inſtrument are rendered impotent by faſtening a box to the braſs tube, ſo that the ball A may move backwards and forwards in the hollow of it, when ſtruck by C. The box ſhould be made of hard wood, and its edge carefully turned and well poliſhed.

120 Cautions.

When a coated jar has been diſcharged, either ſpontaneouſly, or by a diſcharger, there is ſtill a portion of the charge remaining, ſufficient to give a ſlight ſhock, as will be found by graſping the outſide with one hand, and with the other touching the ball of the wire. As this remaining charge, eſpecially in large jars or batteries, is often ſo conſiderable as to give a pretty ſevere ſhock, it is therefore proper to caution the experimenter, not to touch the outſide of the jar or battery, or any conductor which communicates with the inſide at the ſame time.

Every machine will not charge jars equally well, but the power of charging will depend much on the goodneſs of the cylinder.

In a battery it ſometimes happens, that one or more of the jars is more apt than the reſt to undergo a ſpontaneous diſcharge, and in this caſe, the whole of the battery will be diſcharged at the ſame time, although the other jars, without this accident, would have contained a much higher charge.

121 Mr Nairne's mode of preventing the jars of a battery from being broken by a diſcharge.

To remedy the inconvenience of ſome of the jars in a battery burſting at the time of the diſcharge, Mr Nairne propoſed that the diſcharge ſhould not be made through a perfect conductor of a ſhorter circuit than five feet; and this method he found ſo effectual, that after he adapted it, he was able to diſcharge a battery for a hundred times without breaking a ſingle jar, which before was continually happening. It muſt be obſerved, however, as will appear ſoon, that when the circuit through which the diſcharge is made, is conſiderably lengthened, the force of the diſcharge is alſo proportionably diminiſhed. Hence in many experiments, where it is neceſſary to employ the higheſt poſſible charge, this method of diminiſhing the riſk of breaking the jars is inadmiſſible.

122 An inſulated phial cannot be charged.

If a Leyden phial, or any other coated electric, be inſulated or placed ſo that its external coating has no communication with conducting bodies, it cannot be charged.

Place a Leyden phial on the inſulating ſtool, or on a wine glaſs turned mouth downwards; connect the knob of the jar, or its outſide coating, with the prime conductor, by means of a chain, and ſet the machine in motion. It will then be obſerved that the quadrant electrometer on the knob will ſoon riſe to 90°, ſeeming to indicate that the jar is charged. On taking off the connection between the jar and the prime conductor, and endeavouring to diſcharge the jar by means of the diſcharging rod, or by the hands, it will however appear

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appear that the jar has received only a very ſlight charge, as no conſiderable ſpark will ſtrike the ball of the diſcharging rod, and no remarkable ſhock will be felt by the hand.

If now the outſide of the jar, ſtill ſtanding on the inſulator, be connected with the floor, table, &c. by a chain, and then charged, the reſult will be very different as the jar will then receive its uſual charge.

If a jar be inſulated, and one ſide of it, inſtead of being connected with the earth, be connected with the inſulated rubber, while the other ſide communicates with the prime conductor, the jar will be charged, and perhaps in a more expeditious manner.

To make the above experiment in a clearer and more ſatisfactory manner, place the jar upon the ſtool as before, and with its wire not in contact, but at about half an inch diſtance from the prime conductor; hold the knob of another wire at ſuch a diſtance from the outſide coating of the jar, as the knob of the jar is from the prime conductor, then let the winch of the machine be turned, and it will be obſerved, that whenever a ſpark comes from the prime conductor to the wire of the jar, another ſpark paſſes from the outſide coating of the jar to the knob of the wire preſented towards it. In this manner the jar becomes charged.

If inſtead of the knobbed wire, a pointed wire be preſented to the outſide of the jar, the point will appear illuminated with a ſtar; and if inſtead of preſenting any wire to the jar, a point be connected with its coating, the point will appear illuminated with a bruſh of rays which will laſt as long as the jar is charging.

If the knob of another jar be preſented to the outſide coating of the inſulated jar in the above experiment, it will alſo be charged.

123
The charge of a coated electric reſides in the electric.

The charge of a coated jar, or any coated electric, reſides in the jar, or electric, and not in the coating.

Take an uncoated phial, and, for a coating on the outſide, ſtick a piece of tinfoil with a little tallow or bees wax, ſo that it can juſt adhere to the glaſs; and for an inſide coating put into the jar a quantity of ſmall ſhot or of mercury: ſtop the mouth of the jar with a perforated cork, through which inſert a knobbed wire, ſo as to communicate with the ſhot or the mercury. Then hold the phial thus coated, by its outſide coating, and charge it by preſenting the knob of the wire to the prime conductor. When it is charged, turn it upſide down, ſo that the wire, and the mercury or ſhot within the jar, may fall into a dry glaſs veſſel; then remove alſo the outſide coating. During this operation the phial does not loſe its charge; and if the ſhot or mercury be examined, it will be found that they are not more electrified than would happen to any other inſulated body of equal conducting power, after having been in contact with the prime conductor. Now replace the outſide coating on the phial, and pour into it the ſhot or mercury; then touch with one hand the outſide coating, and with the other introduce a knobbed wire within the phial ſo as to touch the inſide non-electric, and you will feel a ſhock, which will prove that the jar has loſt very little of its charge by removing the coatings.

The ſame experiment may be more conveniently made by laying a pane of glaſs upon a metal plate, and covering an equal part of the upper ſurface with tin foil, having a ſilk thread faſtened to one of its ſides, by which it may be eaſily taken off when the glaſs is charged, and as eaſily replaced when required.

124
Diſcovered by Dr Franklin.

This important fact, that the charge in a coated electric reſides in the electric and not in the coating, was aſcertained by Dr Franklin.

When he firſt began his experiments upon the Leyden phial, he imagined that the electric power was all accumulated in the ſubſtance of the non-electric in contact with the glaſs; but he afterwards found by the following ingenious analyſis of the bottle, that the power of giving a ſhock lay in the glaſs itſelf, and not in the coating.

In order to find where the ſtrength of the charged bottle lay, he placed it upon glaſs; then firſt took out the cork and the wire, and finding the virtue was not in them, he touched the outſide coating with one hand, and put the finger of the other into the mouth of the bottle, when the ſhock was felt quite as ſtrong as if the cork and the wire had been in it. He then charged the phial again, and pouring out the water into an empty bottle inſulated, expected that if the force reſided in the water it would give the ſhock, but he found it gave none. He then judged that the electric fire muſt either have been loſt in decanting, or muſt remain in the bottle, and the latter he found to be true; for filling the charged bottle with freſh water, he found the ſhock, and was ſatisfied that the power of giving it reſided in the glaſs itſelf.

He made the ſame experiment with panes of glaſs, laying the coating on lightly, and changing it as he had before changed the water in the bottle, and the reſult was the ſame in both. This experiment is more ſatisfactory than the former; becauſe when the water is poured out of the phial, there ſtill remains a thin coating of the fluid, which might be thought to contain the power of giving a ſhock.

125
A charged jar may be gradually diſcharged by making a conducting body communicate alternately with the outſide and the inſide coating.

126
The electrified ſpider.
Plate CLXXXVIII.

Experiment 1.—Fig. 33. repreſents an electric jar, having a wire, CDE, faſtened on its outſide, which is bended ſo as to have its knob E as high as the knob A. B is the figure of a ſpider formed out of a piece of cork ſlightly burned, with a few ſhort threads run through it to repreſent its legs. This ſpider is to be faſtened at the end of a ſilk thread, proceeding from the ceiling of the room, or any other ſupport, ſo that the ſpider may hang midway between the two knobs AE, when the jar is not charged. Let the place of the jar upon the table be marked; then charge the jar, by bringing its knob A in contact with the prime conductor, and replace it in its marked place. The ſpider will now begin to move from knob to knob, and continue this motion for a conſiderable time, ſometimes for ſeveral hours.

This experiment is one of the earlieſt that were made by Dr Franklin and his friends, and is deſcribed by Dr Franklin in one of his letters to Collinſon.

Exper. 2.—Let a coated jar be inſulated by paſſing it through a ring fixed upon a glaſs ſtand, as repreſented at fig. 34. From the ball *a* of the wire which communicates with the inſide coating ſuſpend a wire to which

which are hung three bells and two clappers, and ſuſpend a ſimilar wire with the ſame number of bells and clappers from the ball, *b*, of a wire which is made to communicate with the outſide coating. Hang the chain *q* to the wire *a*, ſo that it does not touch the table, and charge the jar by holding the knob *a* to the prime conductor. While the jar is charging, the bells hanging from *b* will ring. When the jar is charged, remove it from the prime conductor, and unhook the chain *g*, by means of a wire faſtened to a glaſs handle, and let it lie on the table. If now the ball *b* be touched, the bells which are ſuſpended from it will ceaſe ringing, and the bells ſuſpended from *a* will ring, and will continue to ring for a conſiderable time if not touched. But, now again, if *a* be touched, theſe bells will ceaſe, and thoſe at *b* will begin to ring, and thus each ſet may be made to ring alternately, but never both ſets at once till the bottle is diſcharged.

127 Lateral exploſion.

If a jar be diſcharged with a diſcharging rod that has no electric handle, the hand that holds it, in making the diſcharge, feels ſome kind of ſhock, eſpecially when the charge is conſiderable.—In other words: A perſon, or any conducting ſubſtance, that is connected with one ſide of a jar, but forms no part of the circuit, will feel a kind of ſhock, i. e. ſome effect of the diſcharge. This may be rendered viſible in the following manner. Connect with the outſide of a charged jar a piece of chain; then diſcharge the jar through another circuit, as for inſtance, with a diſcharging rod in the common way, and the chain that communicates with the outſide of the jar, and which makes no part of the circuit, will appear lucid in the dark, i. e. ſparks will appear between the links. This chain will alſo appear luminous, when it is not in contact with the outſide of the jar, but only very near it; and on making the diſcharge, a ſpark will be ſeen between the jar and the end of the chain near it. This electrical appearance out of the circuit of a diſcharging jar, is that which we call the *lateral exploſion*: and to make it appear in the moſt conſpicuous manner, obſerve the following method, which is that of Dr Prieſtley.

When a jar is charged, and ſtands upon the table as uſual, inſulate a thick metallic rod, and place it ſo that one of its ends may be contiguous to the outſide coating of the jar; and within about half an inch of its other end, place a body of about ſix or ſeven feet in length, and a few inches in breadth; then put a chain upon the table, ſo that one of its ends may be about one inch and a half diſtant from the coating of the jar; to the other end of the chain apply one knob of the diſcharging rod, and bring the other knob to the wire of the jar in order to make the exploſion. On making the diſcharge in this manner, a ſtrong ſpark will be ſeen between the inſulated rod, which communicates with the coating of the jar, and the body near its extremity, which ſpark does not alter the ſtate of that body in reſpect to electricity; hence it is imagined, that this lateral ſpark flies from the coating of the jar, and returns to it at the ſame inſtant, allowing no perceptible ſpace of time, in which an electrometer can be affected. Whether this lateral exploſion is received on flat and ſmooth ſurfaces, or upon ſharp points, the ſpark is always equally long and vivid.

CHAP. IV. *Of the methods of diſtinguiſhing Poſitive and Negative Electricity.*

THESE ſtates of electricity are uſually diſtinguiſhed by means of the common pith-ball electrometer.

128 Poſitive and negative electricity diſtinguiſhed by the electrometer.

Experiment.—Set the machine in motion, while both conductors are inſulated, or without connecting either the prime conductor or the rubber with contiguous bodies. We have before remarked (44), that the prime conductor was called the *poſitive*, and that to which the rubber is adapted the *negative* conductor; that they are ſo in theſe circumſtances may be demonſtrated according to the explanation given in note (D).

On preſenting a pith-ball electrometer to the cylinder whoſe electricity we have agreed to call *poſitive*, the balls will diverge, and will continue to diverge when brought near that ſide of the prime conductor which is moſt remote from the cylinder; but being carried to the other conductor, they will inſtantly collapſe; thus ſhowing that the electricity of the rubber is oppoſite to that of the other conductor or of the cylinder, i. e. that it is negative. This may be ſhown in another way. The balls preſented to the rubber will diverge with negative electricity, but being brought near the other conductor in this divergent ſtate, they will collapſe.

But ſhould a more preciſe method be required to determine the quality of the electricity of an electrified body, the following may be uſed:—Firſt, electrify one of the electrometers C, placed upon the ſtand fig. 15, either poſitively, or negatively, at pleaſure: touch it, for inſtance, with an excited glaſs tube, ſo that its balls may repel, and ſtand about two inches diſtant from one another; then touch the other electrometer C with the electrified body, that you deſire to examine, ſo that it may be poſſeſſed of the ſame degree of electricity: laſtly, take either of the two electrometers by the top of the glaſs handle, diſengage it from the arm of the ſtand, and bring it near the other electrometer; if then the balls of one electromer repel thoſe of the other, you may conclude that they are poſſeſſed of the ſame kind of electricity; but if they attract each other, you may conclude that they have been electrified with contrary electricities; and as you know the electricity of that electrometer, which was firſt electrified, you will of courſe know the electricity of the other electrometer, i. e. of the electrified body, with which it was touched.

The above experiment may be alſo made with the ſingle-thread electrometers; for if they are brought near to one another, when their feathers are electrified, they will, if poſſeſſed of the ſame electricity, repel each other, or, if poſſeſſed of contrary electricities, they will attract each other.

129 By the light.

While the conductors are thus inſulated, if a pointed body (as for inſtance, the point of a needle or pin) be preſented to the back of the rubber, at the diſtance of about two inches, a lucid pencil of rays will appear to proceed from the point preſented, and diverge towards the rubber.

If another pointed body be preſented to the prime conductor, it will appear illuminated with a ſtar; but

if

Principles of Electricity illuſtrated by experiment.

if a pointed wire, or other pointed conducting body, be connected with the prime conductor, it will throw out a pencil of rays.

F. Beccaria remarks, that if two equally ſharp points are approached to a prime conductor, they will appear luminous at only half the diſtance at which one of them would have done.

From this experiment may be learned the method of diſtinguiſhing the quality of the electricity of an electrified body, by the appearance of the electric light; for if a needle, or any other pointed body, be preſented in the dark, with the point towards a body ſtrongly electrified, it will appear illuminated with a ſtar, when that body is electrified poſitively, and with a pencil or bruſh, when it is electrified negatively (Q).

Here it is proper to remark, that when two points (one of which is connected with the prime conductor, or the rubber) are oppoſed to one another, the appearance of light in both is pretty much the ſame. Mr Wilcke remarks, that when a point not electrified, is oppoſed to another point electrified poſitively, the cones of light, which otherwiſe would appear upon them, diſappear; but that if a poſitive cone be oppoſed to a negative cone, they both preſerve their own characteriſtic properties †.

† Wilcke, p. 240.

Mr Nicholſon has given us ſome valuable obſervations on the different appearances of the electric light, when proceeding from bodies electrified *poſitively* or *negatively*.

130 Mr Nicholſon's experiments on the light produced by poſitive and negative electricity.

"The eſcape of negative electricity from a ball," ſays Mr Nicholſon, "is attended with the appearance of ſtraight ſharp ſparks with a hoarſe or chirping noiſe. When the ball was leſs than two inches in diameter, it was uſually covered with ſhort flames of this kind, which were very numerous.

"When two equal balls were preſented to each other, and one of them was rendered ſtrongly poſitive, while the other remained in connection with the earth, the poſitive bruſh or ramified ſpark was ſeen to paſs from the electrified ball: when the other ball was electrified negatively, and the ball, which before had been poſitive, was connected with the ground, the electricity exhibited the negative flame, or denſe, ſtraight, and more luminous ſparks from the negative ball; and when the one ball was electrified *plus* and the other *minus*, the ſigns of both electricities appeared. If the interval was not too great, the long zig-zag ſpark of the *plus* ball ſtruck the ſtraight plane of the *minus* ball, uſually at the diſtance of about one third of the length of the latter from its point, rendering the other two thirds very bright: ſometimes, however, the poſitive ſpark ſtruck the ball at a diſtance from the negative flame. Theſe effects are repreſented in Plate CLXXXVIII. figs. 35, 36, and 37.

Plate CLXXXVIII.

"Two conductors of three quarters of an inch diameter, with ſpherical ends of the ſame diameter, were laid parallel to each other, at the diſtance of about two inches, in ſuch a manner as that the ends pointed in oppoſite directions, and were ſix or eight inches aſunder. Theſe, which may be diſtinguiſhed by the letters P and M, were ſucceſſively electrified, as the balls were in the laſt paragraph. When one conductor P was poſitive, fig. 39. it exhibited the ſparks of that electricity at its extremity, and ſtruck the ſide of the other conductor M. When the laſt-mentioned conductor M was electrified negatively, fig. 38. the former being in its turn connected with the earth, the ſparks ceaſed to ſtrike as before, and the extremity of the electrified conductor M exhibited negative ſigns, and ſtruck the ſide of the other conductor. And when one conductor was electrified *plus* and the other *minus*, fig. 40. both ſigns appeared at the ſame time, and continual ſtreams of electricity paſſed between the extremities of each conductor, to the ſide of the other conductor oppoſed to it.

"In drawing the long ſpark from a ball of four inches diameter, I found it of ſome conſequence that the ſtem ſhould not be too ſhort, becauſe the vicinity of the large prime conductor altered the diſpoſition of the electricity to eſcape: I therefore made a ſet of experiments, the reſult of which ſhowed, that the diſpoſition of balls to receive or emit electricity, is greater when they ſtand remote from other ſurfaces in the ſame ſtate; and that between this greateſt diſpoſition in any ball, whatever may be its diameter, every poſſible leſs degree may be obtained by withdrawing the ball towards the broader or leſs convex ſurface out of which its ſtem projects, until at length the ball, being wholly depreſſed beneath that ſurface, loſes the diſpoſition entirely. From theſe experiments it follows, that a variety of balls is unneceſſary in electricity: becauſe any ſmall ball, if near the prime conductor, will be equivalent to a larger ball whoſe ſtem is longer.

131 Mr Nicholſon's apparatus by which the action of points is illuſtrated.

"From comparing ſome experiments made by myſelf many years ago with the preſent ſet, I conſidered a point as a ball of an indefinitely ſmall diameter, and conſtructed an inſtrument conſiſting of a braſs ball of ſix inches diameter, though the axis of which a ſtem, carrying a fine point, was ſcrewed. When this ſtem is fixed in the prime conductor, if the ball be moved on its axis in every direction, it cauſes the fine point either to protrude through a ſmall hole in its external ſurface, or to withdraw itſelf; becauſe by this means the ball runs along the ſtem. The diſpoſition of the point to tranſmit electricity may thus be made equal to that of any ball whatever, from the minuteſt ſize to the diameter of ſix inches. See fig. 41. A.

"The effect of a poſitive ſurface appears to extend farther than that of a negative; for the point acts like a ball, when conſiderably more prominent, if it be poſitive, than it will if negative †."

† Phil. Tranſ for 1780.

132 Mr Nicholſon's inſtrument for diſtinguiſhing negative from poſitive electricity.

Fig. 42. repreſents an inſtrument invented by Mr Nicholſon for diſtinguiſhing *poſitive* from *negative* electricity. It conſiſts of two metallic balls, A, B, which may be placed at a greater or leſs diſtance from each other, by means of a joint at C, on which the two branches CA, CB move. Theſe branches are of glaſs covered with varniſh. A ſhort point proceeds from one of the balls B towards the other A. If the two balls be placed near a body which is electrified, ſo

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(Q) The pencil of light exhibited by a point poſitively electrified was firſt ſeen by Mr Grey, though the difference of the two ſtates was not in his time correctly aſcertained.

that the electric power may paſs through them, it may be known whether it is poſitive or negative, that is, whether it is proceeding *from* or *towards* the electrified body. For, ſuppoſing that the electricity paſſes from A to B, there will be a certain diſtance of the balls at which a ſpark will paſs between the balls; but this diſtance will be much ſhorter when the electricity is paſſing from B to A. It is evident that this inſtrument will be of uſe only when the electricity to be examined is ſufficiently ſtrong to give ſparks.

133 Appearance of the light on paper.

The appearances of poſitive and negative electricity are ſufficiently diſtinct in almoſt every experiment which can be made with the exhibition of electric light. Paper is a good ſubſtance for obſerving the viſible paſſage of the electric power. If a ſtrong poſitive electric ſtream be let fall on the flat ſide of an uninſulated ſheet of paper, it will form a beautiful *ſtar* about four inches in diameter, conſiſting of very diſtinct radii not ramified. Negative electricity, in perfectly ſimilar circumſtances, throws many pointed bruſhes to the paper, but forms no ſtar upon it. This experiment is by Mr Nicholſon, and the cylinder of the machine employed in making it was ſeven inches in diameter *.

CHAP. V. *Of the different ſtates of electricity poſſeſſed by the two ſurfaces of a charged electric.*

The oppoſite ſurfaces of a charged electric are in oppoſite ſtates, i. e. one poſitive, and the other negative.

134 Poſitive and negative ſtates of a charged jar proved by the ball-electrometer;

Exper. 1. Inſulate a coated phial, ſuch as is deſcribed in fig. 34. without the bells, and charge it by holding the knob *a* to the poſitive conductor, while the knob *b* communicates with the table. When the phial is charged, hold a pith-ball electrometer to the knob *a*, and the balls will diverge with *poſitive* electricity, as will appear by preſenting them in their diverging ſtate to excited ſealing-wax, when they will collapſe. Now hold the balls to the knob *b*, which communicates with the outer coating of the phial, and they will diverge with *negative* electricity, as will appear by preſenting them to an excited glaſs tube.

If the jar be charged at the negative conductor, theſe appearances will be reverſed; the balls preſented to the knob *a* will diverge with *negative* electricity, and preſented to *b*, they will diverge with *poſitive* electricity.

135 By the appearance of the light.

Exper. 2. Fix a pointed wire into a hole in the knob *b* of the inſulated phial, and fix another wire in the poſitive conductor. Hold the knob *a* to the point in the poſitive conductor, and on turning the cylinder in the dark, a *pencil* of luminous rays will be ſeen diverging from the point in the conductor to the knob *a*, while a ſimilar *pencil* of rays, diverges from the wire fixed in the knob *b*.

If the wire is fixed in the negative conductor, a luminous *ſtar* will appear at each point.

Exper. 3.—Fix a pointed wire into a hole in the knob *a*, while another pointed wire is fixed in *b*, as in the laſt experiment. Preſent the wire in the knob *a* in the dark, to the poſitive conductor, and a luminous *ſtar* will appear at the point *a*, while the point at *b* throws out a *pencil* of luminous rays.

If the point at *a* be preſented to the negative conductor, the luminous *pencil* will appear at *a* and the luminous *ſtar* at *b*.

Plate CLXXXIX.

Exper. 4.—Fig. 43. is an electric jar which ſerves to illuſtrate the contrary ſtates of the ſides of a Leyden phial while charging: BB is the tinfoil coating; C, a ſtand which ſupports the jar; D, a ſocket of metal, carrying the glaſs rod EF, a bent braſs wire pointed at each end, and fixed at the end of the rod G; this rod is moveable in the ſpring tube N at pleaſure: that tube being fixed by a ſocket on the top of the glaſs rod E, the jar is charged by the inſide wire, which communicates with the different diviſions of the inſide coating by horizontal wires.

Place the jar at the conductor as uſual; and when charging, a luminous ſtar will appear upon the upper point of the wire at F, clearly ſhowing, according to the commonly received opinion, that the point is then receiving the electric power. From the upper ring of the coating B, on the outſide of the jar, a ſtream or pencil of rays will at the ſame time fly off, beautifully diverging from the lower point of the wire E upon the bottom ring of the coating of the jar. When the appearances ceaſe, which they do when the jar is charged, let a pointed wire be preſented to the conductor: this will ſoon diſcharge the jar ſilently; during which the point will be illuminated with a ſmall ſpark, while the upper point of the wire will throw off a pencil of rays diverging towards the upper ring of the coating.

136 Courſe of the electric power in the diſcharge ſhewn by the light;

When a charged electric is diſcharged, the electric power paſſes from the poſitive to the negative ſurface.

Exper. 1.—When a jar has been charged at the poſitive conductor, take a diſcharging rod, furniſhed with pointed extremities, and hold it in ſuch a poſition, that one point ſhall be at the diſtance of about an inch from the knob of the jar, while the other point ſhall be at nearly the ſame diſtance from the outſide coating. In this way the jar will be ſilently diſcharged, and if the experiment be made in the dark, a luminous *ſtar* will appear at that point which is held to the knob of the jar, and a luminous *pencil* at the point which is held to the outer coating.

If the jar has been charged at the *negative* conductor, the appearance of the light at the points will be reverſed; a luminous *pencil* will now appear at the point which is held to the knob of the jar, and a luminous *ſtar* at that which is held at the outer coating.

137 By the direction given to the flame of a taper;

Exper. 2.—Remove the circular piece of wood GH, from the univerſal diſcharger, fig. 29, fix the wires; EF, ET, ſo that their knobs FT may be about two inches diſtant from one another. Then fix upon the ſocket from which the board was removed, a ſmall lighted wax taper ſo that its flame may be juſt in the middle between the knobs FT. When the apparatus is thus diſpoſed, if the outſide of a charged jar be connected by means of a chain or other conducting ſubſtance, with one of the wires, and the knob of the jar be brought to the other wire, it will be obſerved, that, on making the diſcharge which muſt paſs between the knobs FT, the flame of the taper will be driven in the direction of the electric power, i. e. it will be blown towards the knob of that wire which communicates with that ſurface of the jar which is negatively electrified.

Exper. 3.—Fig. 44. and 45. of Plate CLXXXIX. repreſent a ſmall phial coated on the outſide, about three inches

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* *Nicholſon's Phil. Journ.* vol. ii. p. 438.

138 By the Leyden vacuum;

inches up, with tin-foil; at the top of the neck of this phial, is cemented a braſs cap, having a hole with a valve, and from the cap a wire proceeds a few inches within the phial, terminating in a blunt point. When this phial is exhauſted of air, a braſs ball is to be ſcrewed on the braſs cap, ſo as to defend the valve, and prevent any air from getting into the exhauſted glaſs. This phial exhibits clearly the direction of the electric power, both in charging and diſcharging; for if it be held by its bottom, and its braſs knob be preſented to the prime conductor poſitively electrified, you will ſee that the electric power cauſes a *pencil* of rays to proceed from the wire within the phial, as repreſented fig. 45. and when it is diſcharged, a *ſtar* will appear in the place of the pencil, as repreſented in fig. 44. But if the phial be held by the braſs cap, and its bottom be touched with the prime conductor, then the point of the wire, on its inſide, will appear illuminated with a *ſtar* when *charging*, and with a *pencil* when *diſcharging*. If it be preſented to a prime conductor electrified negatively, all theſe appearances, both in charging and diſcharging, will be reverſed.

This experiment of the Leyden vacuum, as it is called, is an invention of the late Mr Henly.

Exper. 4.—Fig. 46. repreſents an electric jar, whoſe exterior coating is made up of ſmall pieces of tin-foil placed at a ſmall diſtance from each other. This jar is to be charged in the uſual manner, when ſmall ſparks will paſs from one piece of tin-foil to the other, in various directions, forming a very pleaſing ſpectacle. The ſeparation of the tin-foil is the cauſe of this viſible paſſage, from the outſide to the table; and the experiment is ſimilar in appearance to that mentioned. If the jar be diſcharged by bringing a pointed wire gradually to the knob T, the unſealed part of the glaſs between the wire and knob will be agreeably illuminated, attended by a crackling noiſe of the ſparks. If the jar be ſuddenly diſcharged, the whole outſide will be illuminated. The jar, uſed in theſe experiments, muſt be very dry.

139 By the double jar.

Exper. 5.—Fig. 47. repreſents two jars, or Leyden phials, placed one over the other, by which various experiments may be made in order to elucidate the theory of electricity. Bring the outſide coating of the bottle A in contact with the prime conductor, and turn the machine till the bottle is charged; then place one ball of the diſcharging rod upon the coating of B, and with the other touch the knob of the jar A, an exploſion will follow; now place one ball of the diſcharger on the knob A, and bring the other ball to its coating, and you have a ſecond diſcharge. Again, apply one ball of the diſcharger to the coating of B, and carry the other to the coating of A, and it will produce a third diſcharge. A fourth is obtained by applying the diſcharger from the coating of A to its knob.

The outer coating of the upper jar communicating with the inſide of the under one, conveys the electric power from the conductor to the large jar which is therefore charged poſitively: the upper jar does not charge, but when a communication is formed from the outſide of A to the inſide of B, part of the electric power on the inſide of A will be conveyed to the negative coating of B, and the jar will be diſcharged. The ſecond exploſion is occaſioned by the diſcharge of the jar A; but as the outſide of this communicates by conducting ſubſtances with the poſitive inſide of the jar B, if the ball of the diſcharging rod remains for a little time after the diſcharge on the knob of A, part of the electric power of the inſide of A will eſcape, and be replaced by an equal quantity on the outſide from the jar B, by which means A is charged a ſecond time; the diſcharge of this produces the third, and of B the fourth exploſion.

140 Mr Brooke's experiments.

Mr Brooke of Norwich brings the following experiments to prove that the oppoſite ſurfaces of an electric, while charging, are not neceſſarily in oppoſite ſtates of electricity.

“ 1. Let two pound phials be coated with tin-foil on their outſides, and filled to convenient height with common ſhot, to ſerve as a coating withinſide, as well as to keep a wire ſteady in the phials without a ſtopple in the mouth of them. Let each phial be furniſhed with a wire about the ſize of a gooſe-quill, and about ten inches long, and let each wire be ſharpened a little at one end, that it may the more eaſily be thruſt down into the ſhot, ſo as not to touch the glaſs anywhere at the mouth of the phials, yet ſo as to ſtand ſteadily in them. Let a metallic ball about ſix or ſeven eighths of an inch diameter be ſcrewed on at the other end of each wire: alſo, let there be in readineſs a third wire, fitted up like thoſe for the phials, except that another ball of nearly the ſame ſize as the former may occaſionally be ſcrewed on at the ſharpened end of it. I ſay, inſtead of ſuſpending the phials from the prime conductor, let one of thoſe above deſcribed be charged at the prime conductor, and then ſet it aſide, but let it be in readineſs in its charged ſtate; then let the other be placed upon a good inſulating ſtand, and let the third wire alſo be laid upon the ſtand, ſo that its ball, or ſome part of the wire, may touch the coating of the phial. Let the ſharpened end of this wire project five or ſix inches over the edge of the ſtand: all of theſe being now placed cloſe to the edge of a table, hang a pair of cork balls on the ſharpened end of the wire, and make a communication from the prime conductor to the ball on the wire on the bottle: on working the machine, the ſharpened end of the wire will permit the bottle to be charged although it be inſulated; and if the wire be very finely pointed, the bottle may be charged nearly as well as if it were not inſulated: I ſay, on working the machine, the phial will charge, and the cork balls will immediately repel each other; but whilſt this phial is charging, take the firſt phial, which having been previouſly charged at the ſame prime conductor in the hand, and while the ſecond phial is charging, preſent the ball of the firſt to the cork balls, and they will all repel each other. This plainly proves that the outſide of the ſecond bottle is electrified *plus* at the time that it is charging, the ſame as the inſide of the firſt; and the inſide of both the bottles will readily be allowed to charge alike, that is *plus* or *poſitive*.

“ 2. Let the ſecond bottle in the laſt experiment be wholly diſcharged, and charge it again as before (the firſt bottle yet remaining charged); and whilſt it is charging, let the ball of the firſt approach the cork balls contiguous with the ſecond, and they will, as before, all repel each other; withdraw the ball of the firſt, and ſo

long

long as the machine continues to charge the ſecond bottle higher, the cork balls will continue to repel each other; but ceaſe working the machine, and the cork balls will ceaſe to repel each other till they touch, and will then very ſoon repel each other again; then let the ball in the firſt phial approach the cork balls, and they will now be attracted by it, inſtead of being repelled as above, as in the laſt experiment. This alſo plainly ſhows, that both ſides of a Leyden phial are alike at the time it is charging; and at the ſame time evidently ſhows, that the difference of the two ſides does not take place till after the bottle is charged, or till the machine ceaſes to charge it higher.

“ 3. In this experiment, let both of the former bottles be diſcharged, then let one of them be placed upon the inſulating ſtand. Let a ball be put on over the ſharpened end of the third wire, and let it be laid on the ſtand as before, ſo as to touch the coating of the phial: place the other phial on the table, ſo that its ball or wire may touch the ball on the third wire, or any part of the wire itſelf: make a communication from the ball on the wire of the firſt phial to the prime conductor: then, by working the machine, both bottles will ſoon become charged. As ſoon as they are pretty well charged, and before the machine ceaſe working, remove the ſecond phial from the third wire; after the ſecond phial is removed, ceaſe working the machine as ſoon as poſſible; take the third wire, with its two balls, off the ſtand with the hand, and lay it on the table, ſo that one of its balls may touch the outſide coating of the ſecond phial: remove the firſt phial off the ſtand, and place it on the table ſo as to touch the ball at the other end of the third wire; then with an inſulated diſcharging rod, make a communication from the ball in one bottle to the ball in the other. If the outſide of the firſt phial be negative at the time it is charging, the inſide of the ſecond will be the ſame, and making the above communication would produce an exploſion, and both bottles would be diſcharged; but the contrary will happen, for there will be no exploſion, nor will either of the bottles be diſcharged, although there be a complete communication between their outſides, becauſe the inſide of them both will be poſitive. This is a proof, that conſidering one ſide of a phial to be poſitive and the other negative at the time they are charging is a miſtake; as well as that, if any number of bottles be ſuſpended at the tail of each other, all the intermediate ſurfaces or ſides do not continue ſo.

“ 4. Here alſo let the apparatus be diſpoſed as in the laſt experiment, till the bottles are highly charged, then with a clean ſtick of glaſs, or the like, remove the communication between the balls of the firſt phial and the prime conductor, before the machine ceaſes working: then, with an inſulated diſcharging rod, make a communication from the outſide to the inſide of the firſt phial; a ſtrong exploſion will take place on account of the exceſs withinſide, notwithſtanding they are both poſitive.

“ 5. This experiment being ſomething of a continuation of the preceding one, immediately after the laſt exploſion takes place, diſcharge the prime conductor of its electricity and atmoſphere; then touch the ball in the firſt phial with the hand, or any conducting ſubſtance that is not inſulated; then will the inſide coating of the firſt phial, which at firſt was ſo ſtrongly poſitive, be in the ſame ſtate as the outſide coating of the ſecond, having a communication with the hand, the floor, &c. with each other; that is negative, if any thing can properly be called negative or poſitive that has a communication with the common ſtock: but a pair of cork-balls that are electrified either *plus* or *minus* will no more be attracted by either the inſide coating of the firſt phial or the outſide coating of the ſecond, than they will by the table on which they ſtand, or a common chair in the room, while they continue in that ſituation. Remove the aforeſaid communication from the ball of the firſt phial; touch the ball in the ſecond, as before in the firſt, or diſcharge the bottle with the diſcharging rod, and the ball in the firſt bottle will immediately become negative; with a pair of cork balls electrified negatively, approach the ball in the firſt phial, and they will all repel each other, or if the cork-balls be electrified poſitively, they will be attracted. All theſe circumſtances together ſerve fully to prove what has already been ſaid, not only that the inſide of the firſt phial, which was ſo ſtrongly poſitive, may be altered ſo as to become in the ſame ſtate as the outſide of the ſecond, without diſcharging the phial, or any more working the machine; but that it may be fairly changed, from being poſitively charged to being negatively charged. If a pair of cork-balls are now hung on to the ball of the wire in this phial, by the help of a ſtick of glaſs, they will repel each other, being negatively electrified. Make a communication from the outſide of the bottle to the table, and replace the communication from the prime conductor to the ball in the bottle; then, upon moderately working the machine to charge the bottle, the cork-balls will ceaſe to repel each other till they touch, and will ſoon repel each other again by being electrified poſitively. Here the working the machine anew, plainly ſhows that the inſide of the firſt bottle, which was poſitive, was likewiſe changed to negative *.”

141 Milner's obſervations and experiments on the Leyden phial.

The following obſervations and experiments on the Leyden phial, are taken from a little work by Dr Thomas Milner.

An electric power communicated to any inſulated conducting ſubſtance has been named ſimple electrification, in order to diſtinguiſh this particular ſtate from that of the charged phial: but it will appear whether this diſtinction ought to be retained or not, by taking a comparative view of both theſe caſes. And, if the changes which an electrical power in general is capable of making in the electrical ſtate of any ſubſtance contained within the ſphere of its influence, be taken into conſideration, and compared with thoſe which have been obſerved in the charged phial, it is apprehended that they will not appear to be different in any material circumſtance.

142 I. In the charged phial, when the inſide has either kind of electricity communicated to it, the outſide is found to poſſeſs a contrary power. It appears alſo that either kind of electricity always produces the other on any conducting ſubſtance placed within the ſphere of influence. And as the ſame effect is alſo produced on electrics themſelves, in the ſame ſituation, and as ſome portion of the air, ſuppoſing no other ſubſtance to be near enough, muſt be unavoidably expoſed to ſuch influence, it neceſſarily follows, that neither power can exiſt

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* *Brooke's Miſcellaneous Experiments*, chap. 3.

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exiſt without the other; and, therefore, in every poſſible caſe, poſitive and negative electricity are inſeparably united.

II. A phial cannot be fully charged in any way by which the outſide acquires a contrary electricity, unleſs the external coating has a communication by ſome conductor with the earth. In the ſame manner a full charge of the contrary electricity cannot readily be procured without a ſimilar communication.

III. In both caſes the interpoſition of an electric body between the contrary powers is abſolutely neceſſary. In one caſe that body is glaſs, in the other it is air; and the experiment will not ſucceed in either, unleſs both the glaſs and the air be tolerably free from moiſture.

IV. It appears that the influence of electricity acts in the ſame manner through glaſs as it does through the air, and produces a contrary power in both caſes.

V. A communication of the electric power is more eaſily made through the fluid yielding ſubſtance of the air than through glaſs, which is ſo hard and ſolid a body, as to require a very conſiderable degree of power to ſeparate its component particles: this however, ſometimes happens, and a hole is made through the glaſs itſelf, without deſign, in attempting to charge a very thin phial as high as poſſible, in the moſt favourable ſtate of the atmoſphere.

VI. A conducting body receives the ſtrongeſt charge of the contrary electricity, when it is brought as near as poſſible to the electric power, without being in the communicating diſtance. And it is well known that the thinneſt phial, if it be ſtrong enough to prevent a communication between the two ſurfaces, will always receive the higheſt charge.

VII. The electricity of the external ſurface of the charged phial cannot be deſtroyed, ſo long as the internal ſurface remains in force, and continues to exert its influence through the glaſs; becauſe this influence was the cauſe of the contrary electricity on the external ſurface, and muſt therefore preſerve it.

VIII. If part of the courſe which the electric power takes in diſcharging a phial be through the air, a ſmall part of the charge will always remain; becauſe the whole of the redundancy on one ſurface is not capable of forcing a paſſage through the reſiſting medium of the air, in order to ſupply the deficiency on the other ſurface. But if every part of the circuit, from the internal to the external coating, conſiſts of the beſt conductors, and if the coated ſurfaces be nearly equal, and directly oppoſite to each other, the phial will then appear to have retained no part of the charge; ſo far as it is covered with tin-foil; but the parts of it above the coating on both ſides will, however, ſtill retain the contrary electricities, after the circuit has been completed. A reſidue of the charge may alſo be obſerved in every other inſtance of electrification, in which the degree of electricity is ſufficient to force a communication between the electrified body and a conductor not inſulated, through a ſmall portion of the air: and if the experiment be carefully made, it will appear, that the whole of the redundancy is not capable of paſſing through the reſiſting intermediate air, in any caſe, and therefore a part of the charge muſt always remain. But here it will be proper to examine more particularly the nature of the charged glaſs.

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143 When a plate of coated glaſs has been charged, and the circuit between the coatings has been completed, by the mediation of a good conducting ſubſtance, no part of the coated ſurface is ſuppoſed to retain any part of the charge; but, according to the commonly received doctrine, the whole of it is ſaid to be diſcharged; or in other words, to be brought into its natural ſtate. This however is not really the caſe, as will evidently appear from the following experiment; the deſign of which is to ſhow the effects produced by charging and diſcharging a plate of glaſs.

Let the middle of a piece of crown window glaſs, ſeven inches ſquare, be placed between two circular plates of braſs, about the 16th part of an inch thick, and five inches in diameter. In order to enable theſe plates to retain a greater degree of power, it will be proper to terminate each of them with a round bead the third part of an inch thick; and the whole of the bead ſhould be formed on one ſide of the plate, that the other ſide may remain quite flat, and apply well to the ſurface of the glaſs. Let the whole be inſulated about four inches above the table, and in a horizontal poſition, by faſtening one end of a cylindrical piece of ſome good inſulating ſubſtance to the middle of the under plate, the other end of it being fixed in any convenient ſtand. Let a like inſulating ſtem be faſtened to the middle of the upper plate. Let a braſs chain, which may eaſily be removed, reach from the under plate to the table. In the laſt place bend a piece of braſs wire into ſuch a ſhape, that it may ſtand perpendicularly on the upper plate; and let the upper extremity of this wire be formed into a book, that it may be removed at any time by the aſſiſtance of a ſilk ſtring, without deſtroying the inſulation of the plate.

The glaſs being thus coated with metal on both ſides, and having alſo a proper communication with the table, will admit of being charged; and both coatings may be ſeparated from the glaſs, and examined apart, without deſtroying the inſulation of either: for the upper coating may be ſeparated by the means of its own proper ſtem; and the under coating may be ſeparated by taking hold of the corners of the glaſs, and lifting the glaſs itſelf. As glaſs readily attracts moiſture from the atmoſphere, it will therefore be neceſſary to warm it in the beginning, and to repeat it ſeveral times in the courſe of the experiment, unleſs the air ſhould be very dry.

144 Excite a ſmooth glaſs tube, of the common ſize, by rubbing it with ſilk, and apply it repeatedly to the bent wire, until the glaſs be well charged. Then remove the chain, which reaches from the lower plate to the table, and alſo the charging wire from the upper plate, by laying hold of its hook with a ſilk ſtring. It neceſſarily follows, from conſidering the quality of the power employed in the preſent caſe, that the upper ſurface of the glaſs, together with the upper coating, muſt be electrified poſitively; and that the under ſurface and coating muſt be electrified negatively; but as it is deſigned in this experiment to examine the powers of charged glaſs, that no virtue may be imputed to the glaſs but what really belongs to it, let both coatings be ſeparated from it; and after they have been brought to their natural ſtate, by touching them with a conducting body not inſulated, let the glaſs be replaced between them; and whatever effects may be now produced muſt be aſcribed ſolely

ſolely to the powers of the charged glaſs. On bringing a finger near the upper coating, a ſmall electrical ſpark will appear between that coating and the finger, attended with a ſnapping noiſe. Apply a finger in the ſame manner to the under coating, and the ſame thing will happen. This effect cannot be produced twice, by two ſucceeding applications to the ſame coating; but it may be repeated ſeveral hundred times over, in a favourable ſtate of the atmoſphere, by alternate applications to the two coatings; and the powers of the glaſs will be thus gradually weakened.

This part of the experiment may be explained, by obſerving that the contrary electricities have a natural tendency to produce and to preſerve each other, on the oppoſite ſides of a plate of glaſs; and therefore, the increaſe or decreaſe of power, on the other ſide: and as in charging a plate of glaſs poſitively, no gradual addition of electric matter can be made to the upper ſurface, without a proper conveyance for a proportionable part to paſs away from the lower ſurface; ſo in this method of uncharging it, the electric power cannot be gradually taken away from the upper ſurface, without adding a proportionable part to the under ſurface: one operation is the reverſe of the other, and ſo are the effects; one caſe being attended with an increaſe and the other with a decreaſe of power.

145 Let the glaſs be again fully charged, and after bringing both coatings to their natural ſtate, as before, let the glaſs be replaced between them; and on touching the upper coating with a finger, and then ſeparating it from the upper and poſitive ſurface of the glaſs by the inſulating ſtem, this coating will acquire a weak negative power, which will be ſufficient to produce a ſmall ſpark while the glaſs is in full force, though after the power of the glaſs has been reduced, it will give little or no ſpark: but in both caſes, on touching the coatings alternately two or three times, the negative power of this coating, when ſeparated from the poſitive ſurface of the glaſs, will be ſo conſiderably increaſed, as to produce ſtrong negative ſparks.—This effect may now be repeated ſeveral times, by only touching the upper coating, but the ſparks will grow weaker every time; and they may be reſtored again to nearly their former ſtrength, by alternate applications to both coatings, as before. The ſame things will alſo happen to the under coating, in the ſame circumſtances; but with this difference, that the power of the under coating, on being ſeparated from the under and negative ſurface of the glaſs will be poſitive. And thus a long ſucceſſion of both poſitive and negative ſparks may be produced in favourable weather, or at any time by keeping the glaſs moderately warm.

It appears from this part of the experiment, that each of the ſurfaces of the charged glaſs has a power of producing a contrary electricity in the coating in contact with it, by a momentary interruption of the inſulation. It neceſſarily follows, in producing theſe effects, that more electrical matter muſt have paſſed away from the upper coating, at the time of touching it, than the ſame coating could receive from the upper ſurface of the glaſs; and therefore the upper coating, by loſing ſome of its natural quantity, will be negatively electrified; and alſo that more electric matter muſt have been added to the under coating at the time of touching it, than the under ſurface of the glaſs could receive from it; and therefore the under coating, by receiving ſome addition to its natural quantity, will be poſitively electrified. It appears further, that the greateſt degree of this influential power, which may be conſiſtent with the circumſtances of the caſe, will be produced in either coating by taking care at the ſame time to bring the oppoſite coating into a like ſtate of influential electricity; and thus it is evident, that the influential powers of the two coatings have the ſame relation to each other, as the contrary powers of the glaſs itſelf, and will therefore always increaſe or decreaſe together.

146 The glaſs being again well charged, as at firſt, let a braſs wire bent in the form of a ſtaple be brought into contact with the upper and lower coating at the ſame time. By this the common diſcharge will be made: but the equilibrium of the coated glaſs will be only reſtored in part; for a conſiderable degree of attraction will happen at the ſame time between the upper coating and the glaſs, which has frequently been ſtrong enough to lift a piece of plate glaſs weighing ten ounces. Neither coating will now ſhow the leaſt external ſign of electricity while it is in contact with the glaſs: but on ſeparating either of them from it, if care be taken to preſerve their inſulations, the upper coating will be ſtrongly electrified negatively, and the under coating will be ſtrongly electrified poſitively. Let then both coatings be brought to their natural ſtate, by touching them when ſeparated from the glaſs, with a conducting body not inſulated, and let the glaſs be replaced between them as before. In this ſtate of things, on touching the upper coating only, and ſeparating it from the glaſs, it will not be capable of giving any ſpark; but on touching the coatings alternately five or ſix times, it will then give a weak ſpark: and this may now be repeated ſeveral times by only touching the upper coating: but on a ſecond application of the bent wire to both coatings at the ſame time, a ſecond diſcharge may be perceived, though much weaker than the firſt, and the coatings will be again brought into the ſame electrical ſtate as immediately after the firſt diſcharge. This may frequently be repeated; and a conſiderable number of ſtrong negative ſparks may be taken from the coating when it is ſeparated from the poſitive ſurface of the glaſs. If the glaſs in replacing it between the two plates be turned upſide down, the electrical powers of both coatings will be changed by the next application of the diſcharging wire to complete the circuit; and a ſucceſſion of ſtrong poſitive ſparks may be taken from the coating when it is ſeparated from the negative ſurface of the glaſs.

It appears from this part of the experiment, that the coated part of the charged glaſs was not brought into its natural ſtate by completing the circuit between the coatings, but that it ſtill retained a degree of permanent electricity; that the powers of both coatings were actually changed at the time of the firſt diſcharge; and that a ſucceſſion of the ſame powers may be produced in the coatings, without renewing the leaſt application of electricity to the glaſs itſelf.

147 The whole quantity of electric power added to the glaſs in charging it, is evidently diſtinguiſhed into two parts in this experiment. The firſt part, which is by far the moſt conſiderable, appears to have been readily communicated from one ſurface of the glaſs to the

other

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other, along the bent wire, when it was firſt brought into contact with both coatings at the ſame time. The ſecond part of the charge appears to be more permanent, and remains ſtill united with the glaſs, notwithſtanding the circuit has been completed (R). This permanent electricity, as well as the other, muſt be poſitive on the upper ſurface, and negative on the lower ſurface: becauſe, in the preſent experiment, the charge was given by a ſmooth glaſs tube excited with a ſilk rubber. Now, the influence of the oppoſite and permanent powers on the different ſides of the glaſs (each ſide having a tendency to bring the coating in contact with it into a ſtate of electricity contrary to its own) muſt aſſiſt each other, in cauſing part of the electric matter naturally belonging to the upper coating to paſs away from it to the under coating, along the diſcharging wire, and at the ſame time the ſurcharge to paſs the ſame way. The upper coating, therefore, by loſing ſome part of its natural quantity, muſt be negatively electrified; and the under coating, by receiving an addition to its natural quantity, muſt be poſitively electrified. The whole quantity of electric matter, which the influence of the permanent electricity of the glaſs is capable of taking from one coating and of adding to the other, bears but a ſmall proportion to the whole charge: and therefore the ſecond and every ſubſequent diſcharge muſt be conſiderably weaker than the firſt.

It appears from ſeveral of the preceding experiments, that a conſiderable degree of influential power may be produced at ſome diſtance by an electric in full force; and therefore a ſmall excited body of a cylindrical ſhape was ſufficient to anſwer that purpoſe: but when the excited electric has been ſo far weakened that it cannot communicate its own power, nor produce this influential power in any body, unleſs it be brought very near or in contact with it, bodies of a cylindrical form muſt then act to great diſadvantage, and a ſmall degree of power only can be produced; becauſe the ſtrength of the influential electricity in this caſe will be in proportion to the ſurfaces of the electric and conducting bodies, which are brought near together, or in contact with each other; and therefore a plate of glaſs in the ſame circumſtances, whether its permanent power be derived from excitation or communication, is enabled from its ſhape to produce a conſiderable degree of the influential powers in the coatings in contact with it.

148
How to charge a phial without friction.

It has been very properly recommended to uſe a particular kind of rubber, and to attend to the ſtate of it, in order to excite glaſs well; but it will not be neceſſary to pay the leaſt regard to theſe circumſtances in the following experiments, in which a method will be ſhown of charging a ſmall phial and a plate of glaſs at the ſame time, by a gradual accumulation of power; that power being entirely derived from the glaſs itſelf, and with no other degree or kind of friction than is neceſſarily connected with the form of the experiment.

Place a circle of tin-foil five inches in diameter on the table, between a ſoft piece of baize and the middle of the ſame plate of glaſs that was uſed in the laſt experiment, which will thus be coated on the under ſide: and in order to preſerve a proper communication with this coating, let a fillet of tin-foil reach from it beyond the extremity of the glaſs. The ſame inſulated metal cover is to be uſed for the upper coating as before. Let a thin ounce phial of glaſs be filled with braſs filings, and coated with tin-foil on the outſide to about one inch from the top. Let a large braſs wire, the fifth part of an inch in diameter, paſs through the cork of the phial into the filings, about an inch of it being left above the cork, and let the upper extremity of this wire be well rounded. This experiment requires, that the whole conſtruction ſhould be well warmed at firſt; and it will be neceſſary to repeat it at proper intervals, unleſs the atmoſphere ſhould be very dry.

Taking hold of the wire of the phial with one hand, let it be placed on the upper ſurface of the glaſs, and its bottom carried in contact over the middle of the upper ſurface, as far as the tin-foil coating reaches on the under ſide: and during this part of the operation, a finger of the other hand muſt be kept in contact with the fillet of tin-foil. Then lifting the phial by the wire with one hand, let it be placed on the inſulated metal cover, ſuſpended in the air with the other hand; and after ſhifting the hand from the wire to the coating, let the bottom of the phial be placed on the end of the tin-foil fillet. Place the inſulated metal cover on the middle of the glaſs, and touch it with a finger of one hand, while the other hand touches the tin-foil fillet. Now lift the inſulated cover by its ſtem, and bring the head of the cover in contact with the wire of the phial, and a very ſmall ſpark of light will appear between them. Let this be repeated in the ſame manner about 15 times, taking care to preſerve a proper communication between the coating and the floor. Then taking hold of the phial by the coating, let it be replaced on the inſulated cover while it is ſuſpended in the air; and after ſhifting the hand from the coating to the wire, let it be again placed on the middle of the glaſs: and let the bottom be again carried in contact over the middle of the glaſs, holding the wire in one hand, while the other has a proper communication with the tin-foil coating. Let the phial be again returned to the tin-foil fillet as before, and let the inſulated cover be applied repeatedly to the wire, immediately after every ſeparation from the glaſs; and a brighter ſpark, together with a weak ſnapping, will now attend each application, if it be carefully obſerved to touch the cover with one hand before every ſeparation, while the other hand reſts on the fillet of tin-foil. By proceeding in this manner, after the third application of the phial to the glaſs, a very

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(R) Some new terms ſeem to be wanted in order to expreſs with preciſion the different parts of the charge. And if that part of it which cannot be deſtroyed by completing the circuit, ſhould be called *the permanent part of the charge*, or more ſimply *the charge*; then might the other part, or that which may be deſtroyed by completing the circuit, be named the *ſurcharge*.

very weak ſhock will be felt in thoſe fingers which are uſed in completing the circuit of the glaſs; and after repeating two rounds more in the manner before mentioned, the phial will be fully charged. By applying the coating of the phial when it is in full force to the upper ſurface as before, the glaſs plate will get the greateſt power it is thus capable of receiving, and will then give a ſhock as high as the elbows. After this, on attempting to lift the inſulated cover, the glaſs itſelf will generally be lifted at the ſame time, with the tin-foil coating adhering to the under ſurface: but by continuing the ſeparations of the cover from the glaſs, a ſucceſſion of ſtrong negative ſparks may be produced by the influence of the upper ſurface; and by turning the glaſs over, and leaving the tin-foil coating on the baize, a ſucceſſion of ſtrong poſitive ſparks may be produced by the influence of the other ſide.

This experiment may be performed more ſteadily by placing the glaſs, together with the tin-foil coating and baize, on a plate of metal about one-tenth of an inch thick, and of the ſame ſquare as the glaſs. The whole may be faſtened together by two ſmall holdfaſts placed at the oppoſite corners, which will prevent the glaſs from being lifted. This plate of metal will be uſeful in another view; for after it has been ſufficiently warmed, by retaining heat well, it will help to keep the glaſs dry, and conſequently fit for uſe ſo much the longer. But when it ſhall be required to ſhow the contrary powers of the oppoſite ſides of the glaſs, it will be more convenient not to faſten the parts together, and the whole may be kept ſufficiently ſteady, by the operator's keeping down one corner of the glaſs with a finger, and by placing a proper weight on the oppoſite corner.

The bottom of the phial cannot be carried in contact over the glaſs without producing ſome little degree of friction; from which the power in this experiment is originally derived. The cover will appear on examination to be electrified negatively after every ſeparation from the glaſs: but as it was touched in completing the circuit between the coatings before every ſeparation, it neceſſarily follows, that the cover can have only an influential electricity, and conſequently that the permanent power of the upper ſurface of the glaſs muſt be poſitive. The negative power of the cover is communicated to the wire of the phial, by which the inſide is electrified negatively and the outſide poſitively; and both theſe powers will increaſe with every application, becauſe the circumſtances of the phial are favourable to its charging. The phial muſt be inſulated every time it is required to ſhift the hand from the wire to the coating, or from the coating to the wire; for without this precaution the phial would be diſcharged. By applying the outſide of the phial to the upper ſurface of the glaſs, in the manner above mentioned, the phial will be partly diſcharged on the ſurface: and though it muſt be therefore weakened, the power of the glaſs will be increaſed, and conſequently enabled to produce a proportionably ſtronger effect on the braſs cover, which by the next round of applications will give the phial a ſtronger charge than it had before. And thus a very ſmall degree of original power is firſt generated, and then employed in forming two different accumulations: and by making each of theſe ſubſervient to the increaſe of the other, the phial is at laſt fully charged, and the glaſs plate acquires ſuch a degree of the ſurcharge, as to give a pretty ſmart ſhock; and after, it remains capable, by the influence of its permanent powers, of producing a ſucceſſion of poſitive and negative ſparks on the oppoſite ſurfaces.

The contrary charge may be given to the phial by taking hold of the coating, and carrying the wire in contact over the middle of the upper ſurface of the glaſs, and by applying the power of the inſulated cover to the coating; for if the operation be conducted in every other reſpect in the ſame manner as before, then will the inſide be electrified poſitively, and the outſide negatively. The powers of the glaſs plate will be the ſame as they were in the former caſe.

After the phial has been fully charged negatively, by the proceſs of the laſt experiment, let it be inſulated; and taking hold of the wire, let the bottom be held uppermoſt, and let the hand which holds it reſt on the fillet of tin-foil. Apply the inſulated cover to the glaſs, and after touching it with a finger of the other hand, ſeparate it from the glaſs; and on bringing it towards the coating of the phial, a ſtrong ſpark will paſs between them. After repeating this between 20 and 30 times, the powers of the phial will be deſtroyed; and by continuing the ſame operation, they will be inverted; for the inſide will be at laſt fully charged poſitively, and the outſide negatively.

The ſame effect may be produced by turning the glaſs over, and by repeatedly applying the influential electricity, produced on that ſide, to the wire of the phial.

When the phial has been fully charged negatively, as in the laſt experiment, take hold of the coating of the phial with one hand, and while the other hand reſts on the tin foil fillet, apply the wire to the middle of the upper ſurface of the glaſs, as far as the tin-foil coating extends on the other ſide. By this the powers of the glaſs plate will be changed.

149 Another, and perhaps a better method of applying the phial, is to place the inſulated cover on the ſurface of the glaſs, and then holding the phial by the coating in one hand, to apply the wire to the cover, while the other hand touches the fillet of tin-foil; by which a ſhock will be given, and the ſame change of powers will be produced in an inſtant, which before took up ſome little time. On lifting the inſulated cover by its ſtem immediately after the ſhock, it will be negative, or have the ſame power as the inſide of the phial; but on replacing the cover, and completing the circuit of the glaſs plate, the ſurcharge will be deſtroyed; another ſhock will be felt; and the power of the cover, after the next ſeparation, will be poſitive, or contrary to that of the inſide of the phial. Apply this poſitive power to the wire of the phial as before; and after 15 applications, the powers of the phial will be deſtroyed; and by ſtill proceeding in the ſame manner, the powers of the phial will be changed, and the inſide will be fully charged poſitively, and the outſide negatively, by 60 applications.

Theſe effects may alſo be produced by a ſingle application of the coating of the phial to the other ſide of the glaſs plate; and by repeated applications of the influential electricity, produced on the ſame ſide, to the coating of the phial.

150 If it were ſimply the object in this experiment to change

change the powers of the phial, the operation might then be conſiderably ſhortened, by completing the circuit of the phial, and conſequently deſtroying the whole ſurcharge: but it was intended to ſhow what effects might be produced, by oppoſing the contrary powers to each other; and by doing this it appears that either ſide of the glaſs plate can deſtroy the powers of the phial, and give it a contrary charge; that either ſide of the phial can alſo change the powers of the glaſs plate; and that the powers of the glaſs plate, thus inverted, can again deſtroy the powers of the phial, and give it a full charge of the contrary electricity.

Here it may be obſerved, that, in ſome caſes, the quality of the power may be determined by obſervation alone. When the phial employed in the two laſt experiments has been fully charged, it may be known whether the inſide be poſitive or negative from the light which appears at the wire, or from the hiſſing noiſe which attends it: for when the phial has been fully charged poſitively, if the room be ſufficiently darkened, a bright luminous appearance may be ſeen, diverging in ſeparate rays to the diſtance of an inch, attended with an interrupted hiſſing noiſe; and both the light and the noiſe continue a very ſhort time. But when the phial is fully charged negatively, a weaker and more uniform light appears, which does not extend itſelf more than the ſixth part of an inch, and is attended with a cloſer and more uniform hiſſing; and this noiſe and light always continue longer than the former. Even poſitive and negative ſparks, paſſing between the inſulated cover and a finger, may be diſtinguiſhed from each other: for the poſitive ſparks are more divided, give leſs light, make a weaker ſnapping noiſe, and affect the finger leſs ſenſibly than the negative.

The ſtrongeſt ſparks which can be produced in theſe experiments, are thoſe that paſs between the coating of the phial and the inſulated cover, when they poſſeſs the contrary powers; but they will be more particularly vigorous if the coating be poſitive, and the inſulated cover negative *.

CHAP. VI. *Miſcellaneous Experiments with charged Electrics.*

151
Cigna's experiments on charged plates.

Sig. Cigna made ſome curious experiments on the adheſion of electrified plates of glaſs. He laid two of theſe plates well dried, one upon the other as one piece, the lowermoſt of them being coated on the outſide; and, when they were inſulated, he alternately rubbed the uppermoſt plate with one hand, and took a ſpark from the coating of the lower with the other till they were charged; when the coating and both the plates adhered firmly together. Giving a coating to the other ſide, and making a communication between the two coatings, the uſual exploſion was produced. But, though the united electric was thus diſcharged, the plate ſtill cohered, and though no ſign of electricity appeared while they were united, they were, when ſeparated, found poſſeſſed of oppoſite ſtates of electricity.

If the two plates were ſeparated before they were diſcharged, and the coating of each was touched, a ſpark came from each, and when they were again placed together, they cohered as before, but were not capable of giving a ſhock †.

If plates of glaſs, thus coated and electrified, be ſeparated in the dark, flaſhes of light will be perceived between them. By laying the plates together again, and again ſeparating them ſucceſſively, the appearance of theſe luminous flaſhes may be repeated ſeveral times, but always in a weaker degree than the firſt.

Mr Symmer made ſeveral experiments of the ſame kind before Sig. Cigna. He found that when the two plates were coated only on one ſide, they were charged as one plate, and the uncoated ſides adhered together; but when they were coated each on both ſides, they became charged diſtinctly from each other, and did not adhere.

152
Mr Henly's remarks.

Mr Henley, in deſcribing an experiment of this kind, makes the following obſervation. “Crown glaſs, that is, the glaſs commonly uſed for ſaſh-windows, though ſo much thinner, ſucceeds in this experiment as well as the plate-glaſs; but what is very remarkable, the Dutch plates, when treated in the ſame manner, have each a poſitive and a negative ſurface, and the electricity of both ſurfaces of both plates is exchanged for the contrary electricity in the diſcharge. If a clean, dry, uncoated plate of looking-glaſs be placed between the coated looking-glaſs plates, or between the plates of crown-glaſs, it appears after charging, to be negatively electrified on both ſides; but if it be placed between the Dutch plates it acquires, like them, a poſitive electricity on one ſurface, and a negative electricity on the other”.

153
Curious experiment of Profeſſor Richman.

A very curious and elegant experiment on the Leyden phial was made by Profeſſor Richman of Peterſburgh, whoſe unfortunate death will be hereafter related.

He coated both ſides of a pane of glaſs, within two or three inches of the edge, and faſtened linen threads to the upper part of the coating, on both ſides; which, when the plate was not charged, hung down in contact with the coating: but ſetting the plate upright and charging it, he obſerved, that when neither of the ſides was touched by his finger, or any other conductor communicating with the earth, both the threads were repelled from the coating, and ſtood at an equal diſtance from it; but when he brought his finger or any other conductor to one of the ſides, the thread hanging to that ſide fell nearer to the coating, while the thread on the oppoſite ſide receded as much; and that when his finger was brought into contact with one of the ſides, the thread on that ſide fell into contact with it likewiſe, while the thread on the oppoſite ſide receded to twice the diſtance at which it hung originally; ſo that the two threads always hung ſo as to make the ſame angle with one another ‡.

154
Magic picture.

One of the moſt diverting experiments with charged electrics, is that which Dr Franklin calls the *Magic Picture*, and which he deſcribes in the following manner. Having a large mezzotinto print (ſuppoſe of the king), with a frame and glaſs; take out the print and cut a pannel out of it, near two inches diſtant from the frame all round. If the cut be through the picture, it is not the worſe. With thin paſte or gum-water, fix the board that is cut off on the inſide of the glaſs, preſſing it ſmooth and cloſe, then fill up the vacancy by

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* *Milner's Experiments and Obſervations.*

† *Mem of the Acad. of Turin*, for 1765.

‡ *Æpini Tentamen*, p. 335.

gilding the glaſs well with gold or braſs leaf. Gild likewiſe the inner edge of the back of the frame all round, except the top part, and form a communication between that gilding and the gilding behind the glaſs; then put in the board and that ſide is finiſhed. Turn up the glaſs, and gild the foreſide exactly over the back gilding; and when it is dry, cover it, by paſting on the pannel of the picture that has been cut out, obſerving to bring the correſpondent parts of the board and picture together, by which the picture will appear of a piece as at firſt, only part is behind the glaſs, and part is before. Laſtly, hold the picture horizontally by the top, and place a little moveable gilt crown on the king's head.

If now the picture be moderately electrified, and another perſon take hold of the frame with one hand, ſo that his fingers touch its inſide gilding, and with the other hand endeavour to take off the crown, he will receive a ſevere ſhock, and fail in the attempt. The operator who, to prevent it from falling holds the picture by the upper end, where the inſide of the frame is not gilt, feels nothing of the ſhock, and may touch the face of the picture with impunity, which he pretends to be a teſt of his loyalty. If a ring of perſons take a ſhock among them, the experiment is called the *conſpirators* *.

155 Electrical jack.

On the ſame principle that the wires of phials charged differently, will attract and repel differently, is made an *electrical wheel*, which, Dr Franklin ſays, turns with conſiderable ſtrength, and of which he gives the following deſcription. A ſmall upright ſhaft of wood paſſes at right angles through a thin round board, of about twelve inches diameter, and turns on a ſharp point of iron, fixed in the lower end; while a ſtrong wire in the upper end, paſſing through a ſmall hole in a thin braſs plate, keeps the ſhaft truly vertical. About thirty radii of equal length, made of ſaſh-glaſs, cut in narrow ſlips, iſſue horizontally from the circumference of the board; the ends moſt diſtant from the centre, being about four inches apart. On the end of every one a braſs thimble is fixed.

If now the wire of a bottle electrified in the common way, be brought near the circumference of this wheel, it will attract the neareſt thimble, and ſo put the wheel in motion. That thimble, in paſſing by, receives a ſpark, and thereby being electrified is repelled, and ſo driven forwards; while a ſecond being attracted, approaches the wire, receives a ſpark, and is driven after the firſt; and ſo on till the wheel has gone once round; when the thimbles before electrified approaching the wire, inſtead of being attracted as they were at firſt, are repelled, and the motion preſently ceaſes.

But if another bottle which had been charged through the coating, be placed near the ſame wheel, its wire will attract the thimble repelled by the firſt, and thereby double the force that carries the wheel round; and not only taking out the electric power that had been communicated by the thimbles to the firſt bottle, but even depriving them of their natural quantity, inſtead of being repelled when they come again towards the firſt bottle, they are more ſtrongly attracted; ſo that the wheel mends its pace, till it goes with great rapidity, 12 or 15 rounds in a minute, and with ſuch ſtrength, that the weight of 100 Spaniſh, with which it was once loaded, did not ſeem in the leaſt to retard its motion. This is called an *electrical jack*, and if a large fowl was ſpitted on the upper ſhaft, it would be carried round before a fire, with a motion fit for roaſting.

But this wheel, like thoſe driven by wind, moves by a foreign force, viz. that communicated to it by the bottles.

156 Self-moving wheel.

The *ſelf-moving wheel*, though conſtructed on the ſame principles, appears more ſurpriſing. It is made of a thin round plate of window glaſs, ſeventeen inches in diameter, well gilt on both ſides, to within two inches of the circumference. Two ſmall hemiſpheres of wood are then fixed with cement, to the middle of the upper and under ſides, centrally oppoſite, and in each of them a thick ſtrong wire, eight or ten inches long, together making the axis of the wheel. It turns horizontally on a point at the lower end of its axis, which reſts on a bit of braſs cemented within a glaſs ſalt ſeller. The upper end of its axis paſſes through a hole in a thin braſs plate, cemented to a long and ſtrong piece of glaſs; which keeps it ſix or eight inches diſtant from any non-electric, and has a ſmall ball of wax or metal on its top.

In a circle on the table which ſupports the wheel, are fixed twelve ſmall pillars of glaſs, at about eleven inches diſtance, with a thimble on the top of each. On the edge of the wheel is a ſmall leaden bullet, communicating by a wire with the upper ſurface of the wheel; and about ſix inches from it, is another bullet, communicating, in like manner, with the under ſurface. When the wheel is to be charged by the upper ſurface, a communication muſt be made from the under ſurface with the table.

When it is well charged it begins to move. The bullet neareſt to a pillar moves toward the thimble on that pillar, and paſſing by, electrifies it, and then puſhes itſelf from it. The ſucceeding bullet, which communicates with the other ſurface of the glaſs, more ſtrongly attracts that thimble, on account of its being electrified before by the other bullet, and thus the wheel increaſes its motion, till the reſiſtance of the air regulates it. It will go half an hour, and make one minute with another, twenty turns in a minute, which is ſix hundred turns in the whole, the bullet of the upper ſurface giving in each turn, twelve ſparks to the thimbles, which makes ſeven thouſand two hundred ſparks, and the bullet of the under ſurface receiving as many from the thimble, theſe bullets moving in the time near two thouſand five hundred feet. The thimbles are well fixed, and in ſo exact a circle, that the bullets may paſs within a very ſmall diſtance of each of them.

If inſtead of two bullets you put eight, four communicating with the upper ſurface, and four with the under ſurface, placed alternately, (which eight at about ſix inches diſtance, complete the circumference) the force and ſwiftneſs will be greatly increaſed, the wheel making fifty turns in a minute, but then it will not continue moving ſo long.

Theſe wheels may be applied perhaps to the ringing of chimes, and moving light made orreries *.

157 Self-charging Leyden phial.

Mr Cavallo gives the following deſcription of an inſtrument which he calls the *ſelf-charging Leyden Phial.*

Take a glaſs tube of about eighteen inches in length, and an inch, or an inch and a half, in diameter. It is immaterial

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* *Franklin's Letters.*

* *Franklin's Letters.*

immaterial whether one of its ends be cloſed or not. Coat the inſide of it with tin-foil, but only from one open extremity of it about as far as its middle; the other part, which remains uncoated, we ſhall call the naked part of the inſtrument. Put a cork into the aperture of the coated end, and let a knobbed wire paſs through the cork, and come in contact with the coating. The inſtrument being thus prepared, hold it in one hand by the naked part, and with the other hand clean and dry-rub the outſide of the coated part of the tube; but after every three or four ſtrokes you muſt remove the rubbing hand, and muſt touch the knob of the wire, and in ſo doing a little ſpark will be drawn from it. By this means the coated end of the tube will gradually acquire a charge, which may be increaſed to a conſiderable degree. If then you graſp the outſide of the coated end of the tube with one hand, and touch the knob of the wire with the other hand, you will obtain a ſhock, &c.

In this experiment the coated part of the tube anſwers the double office of electrical machine and of Leyden phial; the naked part of it being only a ſort of handle to hold the inſtrument by. The friction on the outſide of the tube accumulates a quantity of poſitive electricity upon it, and this electricity forces out of the inſide a quantity of electricity alſo poſitive. Then by taking the ſpark from the knob, this inſide electricity, which is by the coating communicated to the knob through the wire, is removed, conſequently the inſide remains undercharged or negative, and of courſe the poſitive electricity of the outſide comes cloſer to the ſurface of the glaſs, and begins to form the charge. By farther rubbing and taking the ſpark from the knob this charge is increaſed, &c.

Inſtead of a tube, this inſtrument may be conſtructed with a pane of glaſs, in which caſe it will be rather ſimpler, but it cannot be managed ſo eaſily, nor of courſe can it be charged ſo high as the tube. A piece of tin-foil muſt be paſted in the middle of only one ſurface of the pane, leaving about two inches and a half or three inches of uncoated glaſs all round. This done, hold the glaſs by a corner, with the coated ſide from you, and with the other hand rub its uncoated ſide, and take the ſpark from the tin-foil alternately, until you think that the glaſs may be ſufficiently charged; then lay the glaſs with its uncoated ſide flat upon one hand, and on turning the tin-foil with the other hand you will receive the ſhock.

CHAP. VII. *Of the chemical effects of the Electric Spark.*

158 *THE electric ſpark ſets fire to inflammable bodies.*

To fire roſin. *Exper.* 1.—*To fire roſin.* Wrap ſome cotton wool, containing as much powdered roſin as it will hold, about one of the knobs of a diſcharging rod. Then having charged a Leyden jar, apply the naked knob of the rod to the external coating, and the knob enveloped by the cotton to the ball of the wire. The act of diſcharging the jar will ſet fire to the roſin.

A piece of phoſphorus or camphor wrapped in cotton wool, and uſed in the ſame way, will be much more eaſily inflamed.

159 To fire ſpirits. *Exper.* 2.—*To fire ſpirits.* Hang a ſmall ball with a ſtem to the prime conductor, ſo that the ball may project below the conductor. Then warm a little ardent ſpirit, by holding it a ſhort time over a candle in a metallic ſpoon; hold the ſpoon about an inch below the ball, and ſet the machine in motion. A ſpark will ſoon iſſue from the ball and ſet fire to the ſpirits.

This experiment ſucceeds in the very ſame manner, whether the conductor is electrified poſitively or negatively, i. e. whether the ſpark be made to come from the conductor or from the ſpoon; it being only in conſequence of the rapid motion of the ſpark that the ſpirits are kindled.

It will be perhaps ſcarce neceſſary to remark, that the more inflammable the ſpirits are, the more proper they will be for this experiment, as a ſmaller ſpark will be ſufficient to inflame them; therefore rectified ſpirit of wine is better than common proof ſpirit, and æther is better than either.

This experiment may be varied different ways, and may be rendered very agreeable to a company of ſpectators. A perſon, for inſtance, ſtanding upon an electric ſtool, and communicating with the prime conductor, may hold the ſpoon with the ſpirits in his hand, and another perſon, ſtanding upon the floor, may ſet the ſpirits on fire, by bringing his finger within a ſmall diſtance of it. Inſtead of his finger, he may fire the ſpirits with a piece of ice; when the experiment will ſeem much more ſurpriſing. If the ſpoon is held by the perſon ſtanding upon the floor, and the inſulated perſon brings ſome conducting ſubſtance over the ſurface of the ſpirit, the experiment ſucceeds as well.

Mr Winckler ſays, that oil, pitch, and ſealing-wax, might be lighted by electric ſparks, provided thoſe ſubſtances were firſt heated to a degree next to kindling. To theſe it muſt be added, that Mr Gralath fired the ſmoke of a candle juſt blown out, and lighted it again; and that Mr Boze fired gunpowder, melting it in a ſpoon, and fired the vapour that roſe from it *.

This experiment will ſucceed better with a charged jar.

160 To fire hydrogenous gas Plate CLXXXIX. *Exper.* 3. *To fire hydrogenous gas.*—Provide a bottle of ſtrong glaſs with two necks, as *a*, fig. 48. Let a braſs cap be fitted to each neck *c*, *d*; one of which is furniſhed with a cock, and through the other *c*, a glaſs tube *s s* is paſſed, containing a wire projecting beyond the tube at one end, which is terminated by a knob *n*, while the other paſſing within the bottle turns round ſo as to come within an inch of the braſs through which the glaſs tube paſſes. The bottle being thus prepared, fill it with water, and throw up into it equal parts of hydrogen gas and common air, or three parts of hydrogen and one of oxygen gas; fix in the cork, and ſhake the bottle ſo as to mix the gaſes well together. Then bring the knob *n*, near the knob of a charged jar, or a ball of the prime conductor, and the hydrogen will be inflamed with a loud report.

In general the cork will be forced out by the exploſion; but if this ſhould not be the caſe, an opportunity is afforded of proving that the gaſes have diſappeared, and water has been produced by the experiment. On taking out the cork below the ſurface of water, the water will ruſh in, and fill the bottle, thus ſhewing that the *gaſes have diſappeared.*

To prove the production of water, it is neceſſary that the bottle ſhould have been filled with mercury before

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* *Prieſtley, Hiſt. Elect.* per. 7.

before the gaſes were introduced. In both caſes drops of water will appear within the bottle after the report; but where water has been employed in introducing the gaſes, this teſtimony is more equivocal than when *no water* has been uſed.

The firſt perſon who fired inflammable bodies by the electric ſpark, was Dr Ludolf of Berlin, in 1774, who, by ſparks excited by the friction of a glaſs tube, kindled the ethereal ſpirits of Frobenius *. Mr Gordon of Erfurd, produced ſo ſtrong a ſpark from the back of a cat, as to fire ſpirit of wine †.

161 Inflammable air lamp.

Exper. 4.—It has been propoſed by Sig. Volta to apply the burning of hydrogen gas to economical purpoſes, in what he called the *inflammable air lamp*.

A, fig. 49. is a glaſs globe for containing the gas; B a glaſs baſon or reſervoir for holding water; D a cock to form a communication between the water and the gas. The water paſſes into the globe through the metal pipe *g g*, which is fixed to the upper part of the reſervoir A; at *s* is a cock to cut off or open a communication between the air and the jar K. N is a ſmall pipe to hold a piece of wax taper; L a braſs pillar, on the top of which is a ball of the ſame metal; *a*, is a pillar of glaſs with a ſocket at the top, in which ſlides the wire *b*, having a ball ſcrewed on the end of it. F, is a cock by which the globe is filled with hydrogen gas, and which afterwards ſerves to confine the gas and what water falls from B into A.

To uſe this inſtrument, having filled the globe with gas, and the reſervoir A with water, turn the cocks D and *s*, and water will fall into the globe, forcing up a quantity of gas, which will riſe through the pipe K. If now an electric ſpark be made to paſs from the ball *m* to that marked *n*, it will ſet fire to the inflammable gas which paſſes through the pipe K. To extinguiſh the lamp, firſt ſhut the cock *s*, and then D.

The gas is obtained in the uſual way from diluted ſulphuric acid and iron filings, and the globe is to be filled in the following manner. Having previouſly filled it with water, place the foot A in a tub of water ſo that it may be covered, and that the bent glaſs tube through which the gas is to be introduced, may paſs commodiouſly below the foot. When the gas has driven out nearly all the water, turn the cock F, and the lamp is ready for uſe.

162 To fire gunpowder.

Exper. 5. *To fire gunpowder.*—Fix a ſmall cartridge on a metallic wire which is fitted to a glaſs or wooden handle; make a communication between the wire and the ground; then preſent the cartridge to the knob of a charged Leyden phial, and the gunpowder will be fired.

Fig. 50. repreſents a ſmall cannon, with an ivory touch-hole fitted with a braſs pin furniſhed with a round head. Gunpowder may be fired from this cannon by the electric ſhock, in the following manner. Charge the cannon with gunpowder as uſual; then fill the touch-hole with powder, ram it well down, and puſh into it the braſs pin ſo that its end may be near the bottom of the hole. Now make a communication between the outſide of a large charged jar, or a battery, and the body of the cannon; then, placing one ball of a diſcharging rod on the head of the pin, which paſſes down the touch-hole of the cannon, and bring the other to the knob of the jar, and the diſcharge will fire the cannon.

The electric ſpark decompoſes moſt of the compound gaſes, and forms new compounds with their component principles.

163 Action of the electric ſpark on the gaſes.

The firſt who examined the action of electricity on the gaſes, was Dr Prieſtley. In the courſe of his experiments on air, he found that by means of the electric ſpark, he could convert the blue colour of a vegetable infuſion into red. The inſtrument uſed in this experiment, was a glaſs tube about four or five inches long, and one or two tenths of an inch in diameter in the inſide; a piece of wire was put into one end of the tube, and fixed there with cement; a braſs ball was fixed on the top of this wire; the lower part of the tube was filled with water, tinged blue with a piece of turnſole or archil. This was eaſily effected by ſetting the tube in a veſſel of the tinged water, then placing it under a receiver on the plate of an air-pump; exhauſting the receiver in part, and then, on letting in the air, the tinged liquor roſe in the tube, and the elevation would be in proportion to the accuracy of the vacuum; now taking the tube and veſſel from under the receiver, he threw ſtrong ſparks on the braſs ball from the prime conductor.

164 Experiments of Dr Prieſtley.

When Dr Prieſtley made this experiment, he perceived, that after the electric ſparks had been paſſed between the wire and the liquor for about a minute, the upper part of the liquor began to look red; in two minutes it was manifeſtly ſo, and the red part did not readily mix with the reſt of the liquor. If the tube was inclined where the ſparks were paſſed through it, the redneſs extended twice as far on the lower ſide as on the upper. In proportion as the liquor became red, it advanced nearer to the wire, ſo that the air through which the ſparks were paſſed, was diminiſhed; the diminution amounted to about one fifth of the whole ſpace; after which a continuation of the electric ſparks produced no ſenſible effect.

To determine the cauſe of the change of colour, Dr Prieſtley expanded the air in the tube by means of an air-pump, till it expelled all the liquor, and admitted freſh blue colour in its place; but after this, electricity produced no ſenſible effect on the air or on the liquor; ſo that it was clear, that the air had been decompoſed, and ſomething of an acid nature had been produced. The reſult was the ſame with wires of different metals. It was alſo the ſame, when by means of a bent tube, the ſparks were made to paſs from the liquor in one leg of the tube to the liquor in the other. The air thus diminiſhed, was in the higheſt degree noxious.

In paſſing the electric ſpark through different gaſes, it appears of different colours. In *carbonic acid gas*, the ſpark is very white; in *hydrogenous gas*, and *ammoniacal gas*, it appears of a purple or red colour.

Dr Prieſtley found that the electric ſpark paſſed through any kind of oil, produced an *inflammable gas*. He tried it with oil of olives, oil of turpentine, and eſſential oil of mint. The electric ſpark when paſſed through ether, produces the ſame effect.

He found that the electric ſpark when paſſed through *ammoniacal gas*, increaſes the bulk of this gas; ſo that, by making about two hundred ſhocks paſs through a given quantity of it, the original quantity was ſometimes increaſed one fourth. If water was admitted to this gas, it abſorbed the original quantity, and left about as much gas as was generated by the electricity, and this was a ſtrongly inflammable gas.

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* *Phil. Tranſ. Abr.* vol. x.

† *Nollet's Reſearches*, p. 98.

Principles of Electricity illuſtrated by experiment.

Dr Prieſtley found, that on paſſing ſlight electric ſhocks for about an hour, through an inch of *carbonic acid gas*, confined in a glaſs tube one-tenth of an inch in diameter, when water was admitted to it, only one fourth of the air was abſorbed.

He likewiſe found, when the electric ſpark was paſſed through *carbonated hydrogen gas*, that the inſide of the tube in which the gas was confined, was covered with a blackiſh ſubſtance.

Dr Prieſtley took the ſimple electric ſpark from a conductor of a moderate ſize, for the ſpace of five minutes without interruption, in a quantity of *carbonated hydrogen gas*, without producing any change in the inſide of the glaſs; when immediately after, paſſing through it only two ſhocks of a common jar, each of which might be produced in leſs than a quarter of a minute with the ſame machine in the ſame ſtate, the whole of the inſide of the tube was completely covered with the black matter.

A large phial, about an inch and a half wide, being filled with this gas, the exploſions of a very large jar, containing more than two feet of coated ſurface, had no effect upon it; from which it ſeems, that in theſe caſes the force of the ſhock was not able to decompoſe the gas.

Several valuable experiments were made by the Hon. Henry Cavendiſh, of which he gave an account in the 73d volume of the Phil. Tranſ.

165 Mr Cavendiſh's experiments. The apparatus uſed in making the experiments was as follows. The air, through which the ſpark was intended to be paſſed, was confined in a glaſs tube M, bent to an angle, as in fig. 51. which, after being filled with quickſilver, was inverted into two glaſſes of the ſame fluid, as in the figure. The air to be tried, was then introduced by means of a ſmall tube, ſuch as is uſed for thermometers, bent in the manner repreſented by ABC, fig. 52. the bent end of which, after being previouſly filled with quickſilver, was introduced, as in the figure, under the glaſs DEF, inverted into water, and filled with the proper kind of air, the end C of the tube being kept ſtopped by the finger; then, on removing the finger from C, the quickſilver in the tube deſcended in the leg BC, and its place was ſupplied with air from the glaſs DEF. Having thus got the proper quantity of air into the tube ABC, it was held with the end C uppermoſt, and ſtopped with the finger; and the end A, made ſmaller for that purpoſe, being introduced into one end of the bent tube M, fig. 51. the air, on removing the finger from C, was forced into that tube by the preſſure of the quickſilver in the leg BC. By theſe means he was enabled to introduce the exact quantity of ſoap-lees, or any other liquor which he wanted to be in contact with the air.

In one caſe, however, in which he wanted to introduce air into the tube many times in the ſame experiment, he uſed the apparatus repreſented in fig. 53. conſiſting of a tube AB of a ſmall bore, a ball C, and a tube DE of a larger bore. This apparatus was firſt filled with quickſilver, and then the ball C and the tube AB were filled with air, by introducing the end A under a glaſs inverted into water, which contained the proper kind of air, and drawing out the quickſilver from the leg ED by a ſiphon. After being thus furniſhed with air, the apparatus was weighed, and the end A introduced into one end of the tube M, and kept there during the experiment; the way of forcing air out of this apparatus into the tube, being by thruſting down the tube ED a wooden cylinder, of ſuch a ſize as almoſt to fill up the whole bore, and by occaſionally pouring quickſilver into the ſame tube, to ſupply the place of that puſhed into the ball C. After the experiment was finiſhed, the apparatus was weighed again, which ſhewed exactly how much air had been forced into the tube M, during the whole experiment; it being equal in bulk to a quantity of quickſilver, whoſe weight was equal to the increaſe of weight of the apparatus.

Principles of Electricity illuſtrated by experiment.

The bore of the tube M uſed in moſt of the following experiments, was about one-tenth of an inch; and the length of the column of air, occupying the upper part of the tube, was in general from one and a half to three-quarters of an inch.

In order to force an electrical ſpark through the tube, it was neceſſary, not to make a communication between the tube and the conductor, but to place an inſulated ball at ſuch a diſtance from the conductor, as to receive a ſpark from it, and to make a communication between that ball and the quickſilver in one of the glaſſes, while the quickſilver in the other glaſs communicated with the ground.

When the electric ſpark was made to paſs through common air, included between ſhort columns of a ſolution of litmus, the ſolution acquired a red colour, and the air was diminiſhed conformably to what was obſerved by Dr Prieſtley. When lime-water was uſed inſtead of the ſolution of litmus, and the ſpark was continued till the air could be no farther diminiſhed, not the leaſt cloud could be perceived in the lime-water; but the air was reduced to two thirds of its original bulk; which is a greater diminution than it could have ſuffered by mere phlogiſtication, as that is very little more than one-fifth of the whole.

The experiment was next repeated with ſome impure oxygen gas. The gas was very much diminiſhed, but without the leaſt cloud being produced in the lime-water, nor was any cloud produced when carbonic acid gas was let up to it; but on the further addition of a little cauſtic ammonia, a brown ſediment was immediately perceived.

Hence we may conclude that the lime-water was ſaturated by ſome acid formed during the operation; as in this caſe it is evident that no earth could have been precipitated by the carbonic acid gas alone, but that the cauſtic ammonia, on being added, would unite with the carbonic acid, and thus becoming a *carbonate* would precipitate the lime by double affinity; whereas, if the lime had not been ſaturated with an acid, it would have been precipitated on the addition of carbonic acid gas. As to the brown colour of the ſediment, it was probably owing to ſome of the mercury having been diſſolved.

When the impure oxygen gas was confined by ſoap lees, the diminution proceeded rather faſter then when it was confined by lime-water; for which reaſon, as well as on account of this lixivium containing a large quantity of alkali in proportion to its bulk, it ſeemed better adapted than lime-water for experiments deſigned to inveſtigate the nature of the acid produced. Accordingly ſome experiments were made to determine of what degree of purity the oxygen gas ſhould be, in order

order to be diminiſhed moſt readily and in the greateſt degree; and it was found that when good oxygen gas was employed, the diminution was but ſmall; when perfectly pure azotic gas was uſed, no ſenſible diminution took place; but when five parts of pure oxygen gas, and three of common air were employed, almoſt the whole of the gaſes were made to diſappear. It muſt be conſidered that common air conſiſts of one part of oxygen gas mixed with between three and four of azotic gas, ſo that a mixture of five parts of pure oxygen gas and three of common air, was nearly the ſame thing as ſeven parts of oxygen gas and three of azotic gas.

Having made theſe previous trials, Mr Cavendiſh introduced into the tube a little ſoap lees, and then let up ſome oxygen gas and common air, mixed in the above proportions, which riſing to the top of the tube M, diſtributed the ſoap-lees in the two legs of the tube, as faſt as the air contained in it was diminiſhed by the electric ſpark; continuing to add more of the ſame mixture till no further diminution took place; after which a little pure oxygen-gas, and then a little common air were added, in order to ſee whether ceſſation of diminution was not owing to ſome imperfection of the proportion of the two kinds of air to each other, but without effect. The lixivium being then poured out of the tube, and ſeparated from the mercury, ſeemed to be perfectly neutralized, as it produced no change on the colour of paper tinged with the juice of blue flowers. Being evaporated to dryneſs, a ſmall quantity of ſalt was left, which was evidently nitre, as appeared by the manner in which paper impregnated with a ſolution of it burned.

For more ſatisfaction, he tried this experiment over again, on a larger ſcale. About five times the former quantity of ſoap lees were now let up into a tube of a larger bore; and a mixture of oxygen gas and common air, in the ſame proportions as before, being introduced by the apparatus repreſented in fig. 53. the ſpark was continued till no more air could be made to diſappear. The liquor when poured out of the tube, ſmelled evidently of nitrous acid. This ſalt was found by the manner in which paper, dipped into a ſolution of it, burned, to be true nitre. It appeared by the teſt of muriate of baryta, to contain no more ſulphuric acid than the ſoap-lees themſelves often contain, which is in general very little; and there is no reaſon to think that any other acid entered into it, except the nitric.

By theſe beautiful experiments was demonſtrated one of the moſt important facts in modern chemiſtry, viz. that the nitric acid is compoſed of oxygen and azote.

166
Van Marum's experiments on the gaſes.

The above experiments of Prieſtley and Cavendiſh, were repeated on a large ſcale by Dr Van Marum, with the powerful machine in Teyler's muſeum.

For this purpoſe he uſed a cylindrical glaſs receiver five inches long and an inch and a quarter in diameter, into which different ſorts of gaſes were ſucceſſively inſerted, and were confined by quickſilver or water. To a hole made in the bottom of the inverted glaſs receiver, an iron wire was faſtened, the external part of which communicated with a conductor, which being preſented to the prime conductor of the machine, received the ſparks from it. In this diſpoſition of the apparatus it evidently appears, that the ſparks paſſed through the gas contained in the receiver, by going from the inner extremity of the wire to the quickſilver or water in which the receiver was inverted. With this apparatus it was found, that oxygen gas, obtained from mercurial red precipitate, loſt one-twentieth of its bulk; but its quality was not ſenſibly altered, as appeared from examining it with the eudiometer. This experiment being repeated when the receiver was inverted in lime water, and likewiſe in the infuſion of turnſole, there enſued no precipitation, nor change of colour. On pouring out this air, the uſual ſmell of the electric ſpark was very ſenſibly perceived.

Nitrous gas was diminiſhed to more than the half of its original bulk; and in that diminiſhed ſtate, being mixed with common air, it occaſioned no red colour, nor any ſenſible diminution. It had loſt its uſual ſmell, and it extinguiſhed a candle. In paſſing the ſparks through the nitrous gas, a powder was formed on the ſurface of the quickſilver, which is a part of that metallic ſubſtance diſſolved by the nitrous acid.

Hydrogen gas, obtained from iron and diluted ſulphuric acid, communicated a little redneſs to the tincture of turnſole. The ſtream of electricity through this air appeared more red, and much larger, than in common air, being everywhere ſurrounded by a faint blue light.

The inflammable gas, obtained from alcohol and ſulphuric acid, was increaſed to about three times its original bulk, and loſt a little of its inflammability.

Carbonic acid gas, from chalk and ſulphuric acid, was a little increaſed in bulk by the action of electricity; but it was rendered leſs abſorbable by water (T). The

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(T.) It was found by C. Monge, who carefully examined the gas produced by paſſing electric ſparks through carbonic acid gas, that it had been rendered inflammable; and that the mercury employed to confine the gas, as well as the wires between which the ſparks paſſed, were oxidated. C. Monge ſuppoſed that the carbonic acid employed had undergone no change, but that the water held in ſolution by it had been decompoſed; thus accounting for the oxidation of the metals, and the generation of inflammable gas.

M. Theodore de Sauſſure, not conſidering C. Monge's experiments as deciſive, repeated them on a larger ſcale. He cauſed to circulate for 18 hours, electric ſparks in the bulb of a matraſs which contained 13 cubic inches of pure carbonic acid gas, and without any mixture of water ſuperabundant to that which it might naturally hold in ſolution. The mercury in which the inverted matraſs was immerſed roſe to about the half of its neck. After electrization the metallic fluid was found oxidated black, as had been obſerved by Monge and Prieſtley; but his conductors, which were of copper, were not ſenſibly altered. The elaſtic fluid had experienced a ſmall dilatation, which appeared to him not to exceed the tenth part of a cubic inch. He then made about a grain of water to paſs in contact with the aëriform gas contained in the matraſs. He let it remain there for ſeveral days, without perceiving

Principles of Electricity illustrated by experiment.

Principles of Electricity illustrated by experiment.

The gas obtained from ſulphuric acid and charcoal was diminiſhed a little, and black ſpots were formed on the inſide of the glaſs receiver. Afterwards it was obſerved, that only one-eighth part of the electrified gas was abſorbed by water. It extinguiſhed a candle, and had very little ſmell.

Muriatic acid gas ſeemed to oppoſe in great meaſure the paſſage of the electric ſparks, ſince they would not paſs through a greater length than 2¼th inches of this air. It was conſiderably diminiſhed, but the reſt was readily abſorbed by water.

Fluoric acid gas was neither diminiſhed, nor any other way ſenſibly altered, by the electric ſparks.

Ammoniacal gas, extracted from pure ammonia, was at firſt almoſt doubled in bulk; then it was diminiſhed a little; after which it remained without any augmentation or diminution. It became unabſorbable by water; and by the contact of flame it exploded, like a mixture of hydrogen gas and a good deal of common air.

Common air was laſtly tried, and it was found to give a little faint redneſs to the tincture of turnſole; becoming at the ſame time ſenſibly deoxidized. The experiment was repeated thrice at different times, and in each time after the electification it was examined by the admixture of nitrous gas in Mr Fontana's eudiometer, and it was compared with the ſame gas not electrified; the latter always ſuffering the greateſt diminution. In the firſt experiment the diminutions were $\frac{145}{500}$ and $\frac{175}{500}$; in the ſecond, $\frac{159}{500}$ and $\frac{194}{500}$; and in the laſt, $\frac{149}{500}$ and $\frac{178}{500}$.

On attempting to repeat Mr Cavendiſh's experiment deſcribed above, in which he produced the nitric acid by a mixture of oxygen with azotic gas; inſtead of a ſyphon, the Doctor made uſe of a glaſs tube one-ſixth part of an inch in diameter, cloſed at one end, into which an iron wire, $\frac{1}{150}$th of an inch in diameter, had been inſerted: into this tube, filled with mercury, and fixed in a vertical poſition, was introduced the air with which the experiment was to be tried. The oxygen gas was obtained from red preciptate, and had been thoroughly purified by alkaline ſalts, from any acid it might have contained. With a mixture of five parts of this and three of common air, the tube was filled to the height of three inches, to which was added five-twelfths of an inch of lixivium, of the ſame kind with that uſed by Mr Cavendiſh. The reſult was, that, after tranſmitting through the tube a continued ſtream of the electric ſparks during 15 minutes, two inches of the air were abſorbed by the lixivium: more air being introduced into the tube till it was filled to the height of three inches, when it was again electrified. This proceſs was repeated till 8¾th inches of air had been abſorbed by the lixivium: this was now examined, and found to be, in ſome degree, impregnated with the nitric acid; but it was very far from being ſaturated. With the ſame lixivium, of which a quarter of an inch remained in the tube, the experiment was continued till 14 inches more of air had been abſorbed; but its diminution was not perceived to decreaſe, though the lixivium had now abſorbed 77 meaſures of air, each equal to its own; whereas, in the experiment related by Mr Cavendiſh, only 38 meaſures of air were abſorbed by the alkali. But notwithſtanding this greater abſorption, the lixivium was yet far from being ſaturated.

The experiment was repeated with oxygen gas, obtained from minium, moiſtened with the ſulphuric acid; ſeven parts of this were mixed with three of azotic gas, and lixivium added to the height of one-eighth of an inch. Here, as in the former experiment, the diminution continued without any decreaſe; and the lixivium, after it had abſorbed 22¼th inches, and conſequently 178 times its own meaſure of air, was very far from being ſaturated with the nitric acid.

On this Dr Van Marum wrote to Mr Cavendiſh; and finding, by his anſwer, that this gentleman had uſed oxygen gas, obtained from a black powder produced by ſhaking mercury with lead, he requeſted to be informed of the proceſs by which it is generated: but Mr Cavendiſh, not chooſing to communicate this at preſent, he determined to defer the repetition of the experiment till this ingenious philoſopher ſhould have publiſhed his mode of obtaining the oxygen gas uſed in it.

Our author then goes on to ſome experiments made

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perceiving any dilatation in the volume of the gaſes, the reſidue of the operation. He then moiſtened with a drop of water, which he introduced, the whole inſide of the matraſs; but in vain: the mercury conſtantly remained at the ſame height. He, however, found, on abſorbing by potaſh the reſiduum of the acid gas, that a cubic inch of carbonic acid gas had diſappeared, and had been replaced by a quantity nearly equal, or rather ſuperior, to the inflammable gas. The 20 cubic centimetres, occupied in the neck of the matraſs, a column four inches in length; and the acid gas, had the ſuppoſed explanation been juſt, would have been dilated through all that ſpace. He then thought that this inflammable gas did not ariſe from the decompoſition of the water, but from that of the carbonic acid itſelf, by the metal. He indeed found that this gas was not hydrogen gas, but carbonous gas perfectly pure. He burnt 100 parts of it on mercury with about a third of oxygen gas. He did not perceive water after this combuſtion, which left for reſiduum 77 parts of carbonic acid gas.

The dilatation which the latter experiences by electrization may be explained by the different denſities of the carbonous gas and the carbonic acid gas. He was not able to verify the obſervation of C. Monge reſpecting the dilatation experienced by the carbonic acid gas, after electrization over mercury.

If it was not poſſible to reduce entirely the acid gas into carbonous gas by theſe proceſſes, it was becauſe the the firſt ſtrata of metallic oxidation preſented an obſtacle to further oxidation, by preventing the points of contact. The developement of the carbonous gas produced therefore an analogous effect.

It reſults then from his obſervations, that the change which carbonic acid gas undergoes by electrization does not ariſe from the decompoſition of the water, but from the partial decompoſition of the carbonic acid gas, which becomes carbonous gas, giving up a part of its oxygen to the metal introduced in thoſe experiments.

made by ſuffering the electric ſpark to paſs in a continued ſtream through various kinds of air, encloſed for this purpoſe in the little glaſs tube uſed in the laſt experiment.

Oxygen gas obtained the week before from red precipitate, being placed over mercury, and electrified for 30 minutes, was diminiſhed by one-fifth, the ſurface of the quickſilver ſoon began to be oxidated, and towards the end of the experiment the glaſs tube was ſo lined with the oxide as to ceaſe to be tranſparent. By introducing a piece of iron, the electric ſtream was made to paſs through the air without immediately touching the mercury: yet this was equally oxidated. Two inches and three quarters of the ſame kind of gas being placed over water, and electrified in the ſame manner during half an hour, loſt a quarter of an inch; and being ſuffered to ſtand 12 hours in the tube, was found to have loſt one-eighth of an inch more. This was very nearly the ſame diminution of the gas that had taken place when it was electrified over mercury; but, in this caſe, the proceſs appears to have been more ſlow. The gas remaining after theſe experiments, being tried by the eudiometer, did not differ from unelectrified oxygen gas taken from the ſame receiver.

To determine whether the gas retained any of the acid employed in its production, the Doctor repeated the experiment with gas obtained from red precipitate, confined by an infuſion of turnſole, but could not perceive in it the leaſt change of colour. He alſo electrified gas obtained from minium and the ſulphuric acid, placed over ſome diluted acetate of lead; but this was not rendered at all turbid.

Three inches of azotic gas being electrified, during the firſt five minutes were augmented to $3\frac{1}{8}$th inches, and in the next 10 minutes to $3\frac{1}{4}$th inches: ſome lixivium was then introduced to try whether this would abſorb it; but upon being electrified 15 minutes, the column roſe to the height of $3\frac{3}{8}$th inches. It was ſuffered to ſtand in the tube till the next day, when it was found to have ſunk to its original dimenſions.

Nitrous gas, confined by lixivium, being electrified during half an hour, loſt three quarters of its bulk; the lixivium appeared to have abſorbed a great deal of nitric acid; and the gas remaining in the tube did not ſeem to differ from common azotic gas. Some of the ſame nitrous gas, confined by lixivium, was, by ſtanding three weeks, diminiſhed to half its bulk, and this reſiduum alſo proved to be azotic gas.

Hydrogen gas obtained from ſteel filings and the diluted ſulphuric acid, being confined by an infuſion of turnſole, was electrified for 10 minutes without any change of colour in the infuſion, or any alteration in the bulk of the air. The tube being filled with the ſame air to the height of $2\frac{1}{2}$ inches, and placed in diluted acetate of lead, was expoſed to the electric ſtream during 12 minutes, in which time the encloſed gas roſe to five inches; but the acetate remained perfectly clear. Three inches of inflammable gas, obtained from a mixture of alcohol and ſulphuric acid, on being electrified for 15 minutes, roſe to 10 inches; thus dilated, it loſt all its inflammability, and when nitrous gas was added, no diminution enſued.

A column of ammoniacal gas obtained by heat from pure ammonia, three inches high, was electrified four minutes, and roſe to ſix inches, but did not riſe higher when electrified ten minutes longer. It appears that this air is not expanded more by the powerful electric ſtream from this machine than by the common ſpark. Water would not abſorb this electrified air, which was in part inflammable.

The tube, being filled to the height of an inch with ammoniacal gas, and inverted in mercury, was electrified four minutes; in which time the tube was filled with eight inches of gas, which proved to be equally inflammable, and as little abſorbed by water as the ammoniacal gas.

167 Curious experiment with balloons filled with hydrogen gas.

The following experiment is very curious. Two balloons, made of the allantoides of a calf, were filled with hydrogen gas, of which each contained about two cubic feet. To each of theſe was ſuſpended, by a ſilken thread about eight feet long, ſuch a weight as was juſt ſufficient to prevent it from riſing higher in the air; they were connected, the one with the poſitive, the other with the negative conductor, by ſmall wires about 30 feet in length; and being kept near 20 feet aſunder, were placed as far from the machine as the length of the wires would admit. On being electrified, theſe balloons roſe up in the air as high as the wire allowed, attracted each other, and uniting as it were into one cloud, gently deſcended.

168 Electrical air thermometer. Plate CLXXXIX.

The rarefaction of air by the electric exploſion, is well illuſtrated by an experiment of Mr Kinnerſley, thus deſcribed by Mr Cavallo. Fig. 54. Pl. CLXXXIX. repreſents an inſtrument, which the inventor, Mr Kinnerſley, calls the *electrical air thermometer*, it being very uſeful to obſerve the effects of the electric exploſion upon air. The body of this thermometer conſiſts of a glaſs tube AB, about ten inches long, and nearly two inches diameter, and cloſed air-tight at both ends by two braſs caps. Through a hole in the upper cap, a ſmall tube HA, open at both ends, is introduced in ſome water at the bottom B of the large tube. Through the middle of each of the braſs caps, a wire FG, EI, is introduced, having a braſs knob within the glaſs tube, and by ſliding through the caps, they may be ſet at any diſtance from one another. This inſtrument is, by a braſs ring C, faſtened to the pillar of the wooden ſtand CD, that ſupports it. When the air within the tube AB is rarefied, it will preſs upon the water at the bottom of the tube, which will conſequently riſe in the cavity of the ſmall tube; and as this water riſes higher or lower, ſo it ſhows the greater or leſs rarefaction of the air within the tube AB, which has no communication with the external air.

If the water, when this inſtrument is to be uſed, is all at the bottom of the large tube, (i. e. none of it is in the cavity of the ſmall tube) it will be proper to blow with the mouth into the ſmall tube, and thus cauſe the water to riſe a little in it; where, for better regulation, a mark may be fixed.

Bring the knobs GI of the wires IE, FG, into contact with one another, then connect the ring E or F, with one ſide of a charged jar, and the other ring with the other ſide, by which operation a ſhock will be made to paſs through the wires FG, IE, i. e. between the knobs EI. In this caſe you will obſerve, that the water in the ſmall tube is not at all moved from the mark.

Put the knobs GI, a little diſtant from one another, and ſend a ſhock through them as before, and you will ſee that the ſpark between the two knobs, not only diſplaces, but rarefies conſiderably the air; for the water will be ſuddenly puſhed almoſt to the top of the ſmall tube, and immediately it will ſubſide a little, as for inſtance as far as H; which is occaſioned by the ſudden diſplacing and replacing of the air about the place, where the ſpark appeared within the tube AB. After that the water has ſubſided ſuddenly from the firſt riſing, it will then gradually and ſlowly come down to the mark at which it ſtood before the exploſion; which is the effect of the air that was rarefied, and which gradually returns to its former temperature.

If this experiment be made in a room, where the degree of heat is variable, then proper allowance muſt be made for this circumſtance, in eſtimating the event of the experiment; for the electrical air thermometer is affected by heat or cold in general, as well as by that cauſed by an electric ſpark.

169
Decompoſition of water.

In the year 1789, Meſſrs Paets, Van Trooſtwyk, and Deiman, the three aſſociated Dutch chemiſts, as they are generally called, ſent a letter to M. de la Methrie, giving an account of ſome experiments, which they, aſſiſted by Mr Cuthbertſon, had made on the effect of paſſing a ſtream of electricity for a conſiderable time through water. Their letter was printed in the *Journal de Phyſique* for that year; but the account is too long to be inſerted here; we ſhall, therefore, copy the following ſuccinct account of the experiment by Dr Pearſon.

The apparatus employed was a tube 12 inches in length, and its bore was one-eighth of an inch in diameter, Engliſh meaſure; which was hermetically ſealed at one end, and, while it was ſealing, an inch and a half of gold or platina wire was introduced within the tube, and fixed into the cloſed end, by melting the glaſs around the extremity of the wire. Another wire of platina, or of gold, with platina wire at its extremity, immerſed in quickſilver, was introduced at the open end of the tube, which extended to within five-eighths of an inch of the upper wire, which, as was juſt ſaid, was fixed into the ſealed extremity (U).

The tube was filled with diſtilled water, which had been freed from air by means of Cuthbertſon's laſt improved air-pump, of the greateſt rarefying power. As the open end of the tube was immerſed in a cup of quickſilver, a little common air was let into the convex part of the curved end of the tube, with the view of preventing fracture from the electrical diſcharges.

The wire which paſſed through the ſealed extremity was ſet in contact with a braſs inſulated ball; and this inſulated ball was placed at a little diſtance from the prime conductor of the electrical machine. The wire of the lower or open extremity, immerſed in quickſilver, communicated by a wire or chain with the exterior coated ſurface of a Leyden jar, which contained about a ſquare foot of coating; and the ball of the jar was in contact with the prime conductor.

The electrical machine conſiſted of two plates of 31 inches in diameter, and ſimilar to that of Teyler. It poſſeſſed the power of cauſing the jar to diſcharge itſelf 25 times in 15 revolutions. When the braſs ball and that of the prime conductor were in contact, no air or gas was diſengaged from the water by the electrical diſcharges; but on gradually increaſing their diſtance from one another, the poſition was found in which gas was diſengaged, and which aſcended immediately to the top of the tube. By continuing the diſcharges, gas continued to be diſengaged, and aſcend, till it reached nearly to the lower extremity of the upper wire; and then a diſcharge occaſioned the whole of the gas to diſappear, a ſmall portion excepted, and its place was conſequently ſupplied by water.

The reſiduary portion of gas being let out after each experiment, and the diſcharges being continued in the ſame water, this reſiduary gas was left in ſmaller and ſmaller quantity; ſo that after four experiments, probably made on the ſame day, it did not amount to more than 1-80th of the bulk of gas which had been produced. If it had been poſſible to paſs electric ſparks through this very ſmall quantity of gas a ſecond time, or oftener, it was ſuppoſed it would have been diminiſhed ſtill more. But when the tube had been left for a night only filled with water, the reſiduary gas was in greater quantity than after the laſt experiment the preceding day (X).

It was concluded that the gas produced by the electrical diſcharges was oxygen and hydrogen gas, from decompounded water:

1. Becauſe no other gas hitherto known inſtantly diſappears on paſſing through it an electric ſpark.

2. The gas obtained muſt have been the oxygen and hydrogen of decompounded water, becauſe they were in exactly thoſe proportions in which by combination they reproduce water; the trifling reſidue being conſidered to be merely a portion of air which had been diſſolved in the water.

3. Liquids which are not compounded of hydrogen and oxygen, as ſulphuric and nitric acids, afforded gas by the electric diſcharges, but which did not diſappear

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(U) In another part of Mr Van Trooſtwyk's memoir it is ſtated that the diſtance was an inch and a quarter from the end of the upper wire to the top of the lower wire; and that the diſtance between the inſulated ball and prime conductor was at firſt three-fourths of an inch, but that afterwards it was increaſed to an inch. Although the wire faſtened into the top of the tube was ſaid to be an inch and a half in length, it is obſerved, that when a column of three-eighths of an inch of air was collected, it was almoſt at the extremity of the upper wire. From theſe and other inaccuracies, it will be made appear, that no one, from the account publiſhed, has been able to repeat the experiment.

(X) In at leaſt fifty experiments I have never ſeen the reſidue of gas leſs than one-fortieth of the gas produced, although the water had been freed from air by the moſt effectual means. But Mr Schurer (Annales de Chimie, tom. v. p. 276.) teſtifies that he ſaw Mr Van Trooſtwyk make the experiment; and that after it was repeated many times, on the ſame parcel of water, there was no reſidue at all. I have very good grounds for believing, that this is one of the number of inaccuracies in the account publiſhed of this ſubject.

on paſſing through it an electric ſpark; but which did diſappear on adding to it nitrous gas over water. Mr Schurer alſo aſſerts, on the authority of Mr Van Trooſtwyck, that even liquid muriatic acid, which contains a very large proportion of water, affords hydrogen gas only, the oxygen being abſorbed by the muriatic acid, and becoming oxy-muriatic acid.

170
Dr Pearſon's experiments.

Dr Pearſon repeated the above experiments; and has given an ample detail of the manner in which he conducted his experiments, and of their reſult. Our limits will not permit us to give the paper of this ingenious chemiſt at length: we ſhall, therefore, preſent our readers with a brief abſtract of it, referring them for the original to Nicholſon's Journal for September, October, and November 1797, or the Philoſophical Tranſactions for the ſame year.

Dr Pearſon remarks that electric diſcharges may be employed in two manners to decompound water, viz. by what has been termed the *interrupted* exploſion, which was Mr Van Trooſtwyk's method, and the *uninterrupted* or *complete* exploſion.

The Doctor lays down the following requiſites for ſucceeding in this experiment by the *interrupted* exploſion.

1. *The electrical machine muſt poſſeſs ſufficient power.* Dr Pearſon employed a plate machine, conſtructed by Cuthbertſon, which he conſiders as preferable to a cylindrical machine.

2. *The Leyden jar muſt have a ſufficient quantity of coated ſurface.* The Doctor found by experience that the proper quantity was about 150 or 160 ſquare inches, with a proportional prime conductor.

3. *The diſtance between the inſulated ball and the prime conductor muſt always be leſs than the diſtance between the extremities of the wires.*

4. *The extremities of the upper and under wire within the tube muſt be at a certain diſtance from one another.* The diſtance which the doctor generally found to anſwer beſt, was about five-eighths or ſeven-eighths of an inch.

5. *The upper wire fixed into the cloſed extremity of the tube muſt be of a proper length and thickneſs.* The diameter of the upper wire cannot perhaps be too ſmall, and the ſmaller the diameter of the tube, the longer this wire may be.

6. *The tubes muſt be of a proper length and diameter.* The Doctor found the proper length to be nine or ten inches, excluſive of the curved part. The diameter ſhould not be more than one-eighth, or leſs than one-twelfth of an inch.

To ſucceed by the *complete* or *uninterrupted exploſion*, Dr Pearſon uſed the following apparatus.

1. A tube about four or five inches in length, and one-fifth or one-ſixth of an inch in diameter; one end of which was mounted with a braſs cap, and into the other, which was hermetically ſealed, was fitted a *platina* wire of about 1-40th of an inch in diameter, extending into the braſs cap, ſo as to be *almoſt* in contact with it.

2. He alſo employed a tube five inches long and half an inch wide, either blown into a funnel at one end, or having a braſs funnel fitted to it, and inverted in a braſs diſh; a wire, ſuch as the laſt, is ſealed into the other end, and nearly touches the braſs diſh.

The proper diſtance between the wire and diſh muſt be found by trials. In the Doctor's experiments it was about one-twentieth of an inch.

3. The Leyden jar employed muſt contain about 150 ſquare inches of coating.

4. The diſtance between the inſulated ball and the prime conductor was about half an inch.

From his experiments Dr Pearſon draws the following concluſions.

The mere concuſſion by the electric diſcharges, appears to extricate not only the air diſſolved in water, which can be ſeparated from it by boiling and the air-pump, but alſo that which remains in water, notwithſtanding theſe means of extricating it have been employed.

The quantity of this air varies in the ſame, and in different waters, according to circumſtances. New-River water from the ciſtern yielded one-fifth of its bulk of air, when placed by Mr Cuthbertſon under the receiver of his moſt powerful air-pump; but in the ſame ſituation, New-River water taken from a tub expoſed to the atmoſphere for ſome time yielded its own bulk of air. Hence the gas procured by the firſt one, two, or even three hundred exploſions in water containing its natural quantity of air, is diminiſhed very little by an electric ſpark.

The gas thus ſeparable from water, like atmoſpherical air, conſiſts of oxygen and nitrogen, or azotic gas; which may be in exactly the ſame proportions as in atmoſpherical air: for the water may retain one kind of gas more tenaciouſly than the other; and on this account the air ſeparated may be better or worſe than atmoſpherical air at different periods of the proceſs for extricating it.

With regard to the gas, which inſtantly diſappears on paſſing through it an electric ſpark, its nature is ſhewn by (*a*) this very property of thus diminiſhing; and by the following properties:

(*b*) A certain quantity of nitrous gas inſtantly diſappeared, apparently compoſing nitrous acid, on being added to the gas (*a*).

Oxygen gas being added to the reſidue after ſaturation with nitrous gas, and an electric ſpark being applied to the mixture of gaſſes, well dried, a conſiderable diminution immediately took place, and water was produced.

(*c*) Combuſtion from hydrogen and oxygen gas took place when the tube was about three-fourths full of gas, which was confirmed by paſſing an electric diſcharge, under the ſame circumſtances, through a mixture of hydrogen and oxygen gas.

(*d*) Combuſtion from hydrogen and oxygen gas took place when the points of the compaſſes were accidentally applied to the part of the tube containing gas; which was confirmed by paſſing a diſcharge, under the ſame circumſtances, through a mixture of hydrogen and oxygen gas, while the points of the compaſſes were applied to the tube.

(*e*) The obſervations made of the kindling of gas, in ſmall quantities, from time to time, during the proceſs of obtaining it, particularly while it was aſcending in chains of bubbles, or was adhering to the funnel of the tube, confirm the evidence in favour of this gas being hydrogen and oxygen gas.

171
Fuſion of metals by the electric ſpark.

The electric ſpark fuſes and oxidates metals. The firſt experiment to aſcertain the action of electricity on metals

metals was, we believe, made by Dr Franklin. The method in which he made the ſpark fuſe metals was by putting thin pieces of them between two panes of glaſs bound faſt together, and ſending an electric ſhock through them. Sometimes the piece of glaſs by which they were confined, would be ſhattered to pieces by the diſcharge, and be broken into a kind of coarſe ſand, which once happened with pieces of thick looking-glaſs; but if they remained whole, the piece of metal would be miſſing in ſeveral places where it had lain between them, and inſtead of it, a metallic ſtain would be ſeen on both the glaſſes, the ſtains on the under and upper glaſs being exactly ſimilar in the minuteſt ſtroke.

A piece of gold-leaf uſed in this manner appeared not only to have been melted, but even vitrified, as the Doctor thought, or otherwiſe ſo driven into the pores of the glaſs, as to be protected by it from the action of the ſtrongeſt aqua-regia. Sometimes he obſerved that the metallic ſtains would ſpread a little wider than the breadth of the thin pieces of metal. True gold, he obſerved, made a darker ſtain, ſomewhat reddiſh, and ſilver a greeniſh ſtem.

Mr Cavallo gives the following directions for fuſing metallic wires.

Connect with the hook, communicating with the outſide coating of a battery, containing at leaſt thirty ſquare feet of coated ſurface, a wire, that is about one-fiftieth part of an inch thick, and about two feet long; the other end of it muſt be faſtened to one end of the diſcharging rod; this done, charge the battery, and then by bringing the diſcharging rod near its wires, ſend the exploſion through the ſmall wire, which, by this means, will be made red hot, and melted, ſo as to fall upon the floor in different glowing pieces. When a wire is melted in this manner, ſparks are frequently ſeen at a conſiderable diſtance from it, which are red hot particles of the metal, that by the violence of the exploſion are ſcattered in all directions. If the force of the battery is very great, the wire will be entirely diſperſed by the exploſion, ſo that none of it can be afterwards found.

By repeating this experiment with wires of different metals, and the ſame force of exploſion, it will be found that ſome metals are more readily fuſed than others, and ſome not at all affected; which ſhows the difference of their conducting power. If it be required to melt ſuch particles of metals, that cannot eaſily be drawn in wires, as ores, grains of platina, &c. they may be ſet in a train upon a piece of wax; this train may be inſerted in the circuit, and an exploſion may be ſent through it, which, if it be ſufficiently ſtrong, will melt the metallic particles, as well as the wires: or, if the quantity to be tried be large enough, it may be confined in a ſmall tube of glaſs.

If a wire be ſtretched by weights, and a ſhock be made to paſs through it, ſo as to render it juſt red hot, the wire after the exploſion will be found conſiderably increaſed in length, but if the wire be left looſe it will be found after a ſimilar exploſion conſiderably ſhortened *.

If a wire be melted upon a piece of glaſs, the glaſs will after the exploſion be found marked with all the priſmatic colours.

The wire may be formed into globules by incloſing it in a glaſs tube about a quarter of an inch in diameter, and ſending the charge of a battery through it. The wire thus melted, will run into globules, which will adhere to the inner ſurface of the tube, and may be eaſily ſeparated from it. On examination they will be found to be hollow, and are the metal in its leaſt ſtate of oxidation.

Some nicety is required in this experiment, as if the charge be too ſmall, the globule will not be well formed, and if it be too great, the metal will be ſo much oxidated as to be diſſipated in ſmoke.

If a piece of metal be fixed upon each of the knobs of the univerſal diſcharger, or upon the extremities of the wires that ſupport theſe knobs, ſo that their ſurfaces may come ſufficiently near each other for the charge of a battery to be paſſed between them, and if a diſcharge be then made, a ſpot and coloured circles will be formed upon each metallic ſurface, which are evidently owing to a partial oxidation of the metal.

In order to exhibit coloured rings upon the ſurface of metals, place a plain piece of any of the metals upon one of the wires of the univerſal diſcharger, and upon the other wire fix a ſharp-pointed needle, with the point juſt oppoſite to the ſurface of the metal; then connect one wire of the diſcharger with the outſide of a battery, and the other with the diſcharging rod, &c. In this manner, if exploſions be repeatedly ſent either from the point to the piece of metal, or from the latter to the former, they will gradually mark the ſurface of the piece of metal oppoſite to the point, with circles, conſiſting of all the priſmatic colours; which are evidently occaſioned by laminæ of the metal, raiſed by the force of the exploſions.

Theſe colours appear ſooner, and the rings are cloſer to one another, when the point is nearer to the ſurface of the metal. The number of rings is greater or leſs, according as the point of the needle is more ſharp or more blunt; and they are repreſented equally well upon any of the metals.

The point of the needle is alſo coloured to a conſiderable diſtance; the colours upon it returning in circles, though not very diſtinctly. This is an experiment of Dr Prieſtley.

172 Van Marum's experiments on fuſing metals.

But the moſt ſplendid experiments on the fuſion of metals by electricity have been made by Dr Van Marum. He firſt tried the effect of a battery containing 130 ſquare feet of coated ſurface. With this extraordinary power, he melted an iron wire 15 feet long and $\frac{1}{151}$ of an inch in diameter; and another time melted a wire of the ſame metal 25 feet long and $\frac{1}{240}$th of an inch in diameter.

He afterwards added to the battery 90 jars, each of the ſame ſize with the former, ſo that his grand battery now formed a ſquare of 15 feet, and contained 225 ſquare feet of coated glaſs. He cauſed wires of different metals to be drawn through the ſame hole, of one-thirty-eighth part of an inch in diameter, and obſerved how many inches of each could be melted by the exploſion of his battery; taking care in all theſe experiments to charge it to the ſame degree as aſcertained by his electrometer. The reſults were as follows:

Of *lead* he melted	120 inches
Of *tin*	120
Of *iron*	5
Of *gold*	$3\frac{1}{2}$
Of *ſilver*, *copper*, and *braſs*,	not quite a quarter of an inch.

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* Cavallo's *Electricity*, vol. i. p. 310.

Principles of Electricity illustrated by experiment.

Theſe ſeveral lengths of wire, of the ſame diameter melted by equal exploſions, indicate according to our author, the degree in which each metal is fuſible by the electrical diſcharge; and if theſe be compared with the fuſibility of the ſame metals by fire, a very conſiderable difference will be obſerved. According to the experiments of the academicians of Dijon, to melt tin required a heat of 172 degrees of Reaumur's thermometer.

Lead	230
Silver	430
Gold	563
Copper	630
Iron	696 (Y).

Thus tin and lead appear to be equally fuſible by electricity, but not by fire: and iron, which by fire is leſs fuſible than gold, is much more ſo by the electrical exploſion.

When iron wire is melted by the exploſion of the battery, the red hot globules are thrown to a very conſiderable diſtance, ſometimes to that of 30 feet; it is however remarkable, that the thicker the wire is which is melted, the further are the globules diſperſed; but this is accounted for, by obſerving, that the globules formed by the fuſion of the thinner wires, being ſmaller, are leſs able to overcome the reſiſtance of the air, and are therefore ſooner ſtopped in their motion.

Two pieces of iron wire being tied together, the fuſion extended no further than from the end connected with the inſide coating of the jars to the knot; though wire of the ſame length and thickneſs, when in one continued piece, had been entirely melted by an equal exploſion.

When a wire was too long to be melted by the diſcharge of the battery, it was ſometimes broken into ſeveral pieces, the extremities of which bore evident marks of fuſion; and the effect of electricity in ſhortening wire, was very ſenſible in an experiment made on 18 inches of iron wire $\frac{1}{55}$th of an inch in diameter, which by one diſcharge loſt a quarter of an inch of its length. An exploſion of this battery through very ſmall wires, of nearly the greateſt length that could be melted by it, did not entirely diſcharge the jars. On tranſmitting the charge through 50 feet of iron wire of $\frac{1}{240}$th of an inch in diameter, the doctor found that the reſiduum was ſufficient to melt two feet of the ſame wire; but this reſiduum was much leſs when the wire was of too great a length to be melted by the firſt diſcharge. After an exploſion of the battery through 180 feet of iron wire of equal diameter with the former, the reſiduum was diſcharged through 12 inches of the ſame wire which it did not melt, but only blued.

Twenty-four inches of leaden wire $\frac{1}{38}$th of an inch in diameter, were entirely oxidated by an exploſion of this battery; the greater part of the lead roſe in a thick ſmoke, the remainder was ſtruck down upon a paper laid beneath it, where it formed a ſtain which reſembled the painting of a very dark cloud. When ſhorter wires were oxidated, the colours were more varied. In Dr Van Marum's work a plate is given of a ſtain made by the oxidation of this wire, in which the cloud appears variouſly ſhaded with different tints of green, gray, and brown, in a manner of which no adequate deſcription can give an idea.

On diſcharging the battery through 8 inches of tin wire $\frac{1}{38}$th of an inch in diameter, extended over a ſheet of paper, a thick cloud of blue ſmoke aroſe, in which a number of filaments of oxide of tin were diſcernible; at the ſame time a great number of red hot globules of tin, falling upon the paper, were repeatedly thrown up again into the air, and continued thus to rebound from its ſurface for ſeveral ſeconds. The paper was marked with a yellowiſh clouded ſtain immediately under the wire, and with ſtreaks or rays of the ſame colour iſſuing from it in every direction; ſome of theſe formed an uninterrupted line, others were made up of ſeparate ſpots. In order to be certain that the colour of theſe ſtreaks was not cauſed by the paper being ſcorched, the experiment was ſeveral times repeated, when a plate of glaſs and a board covered with tin were placed to receive the globules. Theſe, however, were ſtaine exactly like the paper. On oxidating five inches of the ſame kind of wire, the red hot globules were thrown obliquely to the height of four feet, which afforded an opportunity of obſerving that each globule, in its courſe, diffuſed a matter like ſmoke, which continued to appear for a little time in the parabolic line deſcribed by its flight, forming a track in the air of about half an inch in breadth.

Principles of Electricity illustrated by experiment.

Dr Van Marum attributes the clouded ſtain, immediately under the wire, to the inſtantaneous oxidation of its ſurface; whereas the remainder of the metal is melted into globules, which while they retain their glowing heat, continue to be ſuperficially oxidated, and during the proceſs, part with this oxide in the form of vapour.

Phenomena ſomething ſimilar to the above, were obſerved on the oxidation of a wire of equal parts of tin and lead, eight inches long, and $\frac{1}{32}$d of an inch in diameter. This alſo was melted into red globules, which were repeatedly driven upwards again from the paper on which they fell, and marked it with ſtreaks of the ſame kind, but of a brown colour, edged with a yellow tinge. Some of theſe globules, though apparently not leſs hot, moved with leſs velocity than others, and and were ſoon ſtopped in their courſe by their burning a hole in the paper. In this caſe a yellow matter was ſeen to riſe from their ſurface to the height of one or two lines, and extended itſelf to the width of a quarter of an inch. This matter continued during five or ſix ſeconds,

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(Y) According to the experiments of Mr Wedgewood with his Pyrometer, the following are the degrees of heat computed in degrees of Fahrenheit's ſcale that are required to fuſe certain metals.

Braſs	3807°	
Swediſh copper	4587	
Fine ſilver	4717	
Fine gold	5237	
Caſt iron	39977	*Vid. Phil. Tranſ.* vol. lxxii.

Principles of Electricity illustrated by experiment.

ſeconds, to iſſue from the globules, and formed on their ſurface a kind of effloreſcence, reſembling the flowers of ſulphur produced by the *ſolfa-terra*. The globules, from which this effloreſcence had iſſued, were found to be entirely hollow, and to conſiſt only of a thin ſhell. When this mixed metal is oxidated with a leſs charge of battery, it leaves a ſtain upon the paper, ſomething ſimilar to that made by lead, and does not run into globules.

Dr Van Marum has alſo given plates of the ſtains made upon paper by the oxidation of iron, copper, braſs, ſilver, and gold. Thoſe made by copper and braſs wire, are uncommonly beautiful, and are variegated with yellow, green, and a very bright brown. Eight inches of gold wire, of $\frac{1}{60}$th of an inch diameter, were, by the exploſion reduced to a purple ſubſtance, of which a part roſe like a thick ſmoke, and the remainder on the paper, left a ſtain diverſified with different ſhades of this colour. Gold, ſilver, and copper, cannot eaſily be melted into globules. Our author has once accidentally ſucceeded in this; but it required a degree of electrical force ſo very particular, that the medium between a charge, which only broke the wire into pieces, and one which entirely oxidated it, could not be aſcertained by the electrometer.

Dr Van Marum found, as might be expected, that the electric ſpark did not oxidate metals when confined in any gas which did not contain oxygen. On expoſing wires of lead, tin, and iron, to the electric ſpark from the diſcharge of a battery, while the metals were confined in air deprived of oxygen, by the burning of inflammable bodies in it, he found that the firſt was reduced to a fine powder, which upon trial with nitric acid appeared to be merely lead; the two other metals were melted into ſmall globules. He found that in general metals were not more highly oxidated in pure oxigenous gas than in common air, except that lead was reduced to a fine yellow oxide, perfectly reſembling maſſicot.

In nitrous gas, oxidation took place as eaſily as in common air or in oxigenous gas.

His method of making theſe experiments was as follows. He confined the gas in which he was to ſubject the metal to the exploſion, in a glaſs cylinder ſix inches high and four inches in diameter, cloſed at the upper end with a braſs plate; from the centre of this plate was ſuſpended the wire on which the experiment was made. The cylinder was ſet in a pewter diſh filled with water; and to prevent its being broken by the expanſion of the air, its lower edges were ſupported by two pieces of wood half an inch high. The lower end of the wire reſted on the diſh, which was connected with the outſide coating of the battery.

On ſubmitting metallic wires to the action of the electric ſpark while confined in water, he found that the water was decompoſed, the metal being oxidated, and a portion of impure hydrogenous gas being diſengaged (z).

173 To burn wire in oxygen gas;

Exper.—*To burn a metallic wire in oxygen gas, by the electric ſpark.*

The apparatus for this experiment is repreſented at fig. 55. It conſiſts of a glaſs jar for holding the gas, fitted to the bottom C, ſo that it may eaſily be taken out. Into the bottom is faſtened a braſs knob B, and a wire paſſes through the top of the jar furniſhed with a ball at A, and a knob within the jar as D, into which the piece of wire, twiſted in a ſpiral form, is to be inſerted.

The jar, thus fitted up with the wire, is to be filled with oxygen gas, obtained from the black oxide of manganeſe as deſcribed under CHEMISTRY; and on paſſing the charge of a ſmall Leyden phial through the wire A, an exploſion will take place between the knob B, and the extremity of the ſmall wire, by which this will be inflamed, producing a moſt brilliant and beautiful appearance.

174 *When the electric ſpark is paſſed through a metallic oxide, the oxide is reduced to the metallic ſtate.*

This was effected by Sign. Beccaria, by making the ſpark paſs between two ſurfaces of the oxide. In this way he reduced ſeveral of the metallic oxides, among others, that of zinc. He alſo obtained pure mercury, from the red ſulphuret or cinnabar. †

† *Beccaria Lettre dell' Elettriciſmo.*

175 To illuminate water.

The electric ſpark renders bodies luminous, and makes opaque ſubſtances appear tranſparent.

Exper. 1.—Connect one end of a chain with the outſide of a charged phial, and let the other end lie on the

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(z) Although there was good reaſon to ſuppoſe that the powders produced in the above experiments were real oxides of the metals, yet they had not been proved to be ſo by any ſatisfactory experiment. Dr Van Marum and his ingenious coadjutor (Mr Cuthbertſon), began a ſet of direct experiments for the purpoſe of aſcertaining this point; but the doctor was ſoon diſcouraged by the breaking of apparatus, and nothing ſatisfactory was done. Since Mr Cuthbertſon's return to London, he has carried into execution a ſeries of experiments which he had projected in Holland, and by theſe he has fully proved that metals exploded by the electric ſpark abſorb oxygen from the air and become oxidated, more readily than when fuſed by ordinary fire. We cannot pretend to give any thing like an account of theſe experiments in this note; they are publiſhed at length in Nicholſon's Journal for July 1801. The following are Mr Cuthbertſon's general concluſions.

"From the reſult of the foregoing experiments, it may be ſafely concluded that all the ductile metals can by electric diſcharges be ſublimed and converted into proper oxides, by abſorbing the oxygen from the atmoſphere, and although ſome of the metals reſiſt the action of common fire, and require different ſolvents to convert them into oxides, yet they all yield to the action of electricity.

It is remarkable that platina, though it reſiſts the action of common fire, is more eaſily fuſed by electric diſcharges than copper, ſilver, or gold, and ſeems to be as greedy of oxygen as any of the other metals; but theſe experiments have not been ſufficiently extenſive to ſettle the laſt mentioned property.

It is well known that all metals which are ſublimable by common fire, abſorb oxygen in different degrees, and likewiſe in different proportions, according to the degrees of heat employed; this ſeems to take place alſo when they are ſublimed by electric diſcharges, but the proper degree of diſcharge for each metal remains for inveſtigation.

Principles of Electricity illuſtrated by experiment

the table. Place the end of another piece of chain at the diſtance of about a quarter of an inch from the former; and ſet a glaſs decanter of water on theſe ſeparated ends. On making the diſcharge, the water will appear perfectly luminous.

The electric ſpark may be rendered viſible in water, in the following manner. Take a glaſs tube of about half an inch in diameter, and ſix inches long; fill it with water, and to each extremity of the tube adapt a cork, which may confine the water; through each cork inſert a blunt wire, ſo that the extremities of the wires within the tube may be very near one another; then on connecting one of theſe wires with the coating of a ſmall charged phial, and touching the other wire with the knob of it; by which means the ſhock will paſs through the wires, and cauſe a vivid ſpark to appear between their extremities within the tube. The charge in this experiment muſt be very weak, or there will be danger of burſting the tube.

176 To illuminate eggs. Plate CLXXXIX.

Exper. 2.—Fig. 56. repreſents a mahogany ſtand, ſo conſtructed as to hold three eggs at greater or ſmaller diſtance, according to the poſition of the ſliding pieces. A chain C is placed at the bottom, in ſuch a manner as to touch the bottom of the egg at B with one end, and with its other the outſide coating of a charged jar. The ſliding wire A at top is made to touch the upper egg; and the diſtance of the eggs aſunder ſhould not exceed the quarter or eighth part of an inch. The electric ſpark, being made to paſs down by means of the diſcharging rod through the wire and ball at A, will in a darkened room render the eggs very luminous and tranſparent.

177 *Exper.* 3.—Place an ivory ball on the prime conductor of the machine, and take a ſtrong ſpark, or ſend the charge of a Leyden phial through its centre, and the ball will appear perfectly luminous; but if the charge be not paſſed through the centre, it will paſs over the ſurface of the ball and ſinge it. A ſpark made to paſs through a ball of boxwood, not only illuminates the whole, but makes it appear of a beautiful crimſon, or rather fine ſcarlet colour.

Exper. 4.—Gold-leaf or Dutch metal may be rendered luminous by diſcharging a ſmall Leyden phial through it. A ſtrip of gold leaf, one-eighth of an inch in breadth, and a yard long, will frequently be illuminated throughout its whole extent, by the exploſion of a jar containing two gallons. This experiment may be beautifully diverſified, by laying the gold or ſilver leaf on a piece of glaſs, and then placing the glaſs in water; for the whole gold leaf will appear moſt brilliantly luminous in the water, by expoſing it thus circumſtanced to the exploſion of a battery.

178 To illuminate Canton's phoſphorus.

Exper. 5.—The natural, or what anſwers better, the artificial Bolognian ſtone reduced to powder, (commonly called *Canton's phoſphorus*) may be illuminated by the electric ſpark in a more perfect manner than by the rays of the ſun. The method of making this experiment is thus related by Mr Cavallo.

Put ſome of this powder in a clear glaſs phial, and ſtop it with a glaſs ſtopper, or a cork and ſealing-wax. If this phial be kept in a darkened room (which for this experiment muſt be very dark) it will give no light; but let two or three ſtrong ſparks be drawn from the prime conductor, when the phial is kept at about two inches diſtant from the ſparks, ſo that it may be expoſed to that light, and this phial will receive the light, and afterwards will appear illuminated for a conſiderable time.

Principles of Electricity illuſtrated by experiment.

This powder may be ſtuck upon a board by means of the white of an egg, ſo as to repreſent figures of planets, letters, or any thing elſe, at the pleaſure of the operator, and theſe figures may be illuminated in the dark, in the ſame manner as the above-deſcribed phial.

A beautiful method of expreſſing geometrical figures with the above powder, is to bend ſmall glaſs tubes, of about the tenth part of an inch diameter, in the ſhape of the figure deſired, and then to fill them with the phoſphoric powder. Theſe may be illuminated in the manner deſcribed; and they are not ſo ſubject to be ſpoiled, as the figures repreſented upon the board frequently are.

The beſt method of illuminating this phoſphorus, and that Mr W. Canton generally uſed, is to diſcharge a ſmall electric jar near it.

Paper, after being made dry and rather hot, marble, oyſter ſhells, and moſt calcareous ſubſtances, eſpecially when burned to lime, have the property of being illuminated by the light given by the diſcharge of a jar, though not ſo much as the above-mentioned powder.

Put the extremities of two wires upon the ſurface of a card, or other body of an electric nature, ſo that they may be in one direction, and about one inch diſtance from one another; then, by connecting one of the wires with the outſide of a charged jar, and the other wire with the knob of the jar, the ſhock will be made to paſs over the card or other body. If the card be made very dry, the lucid track between the wires will be viſible upon the card for a conſiderable time after the exploſion. If a piece of common writing paper be uſed inſtead of the card, it will be torn by the exploſion into very ſmall bits.

When the electric diſcharge is paſſed through a lump of ſugar, the ſugar is rendered perfectly luminous, and will retain the light for a conſiderable time.

Exper. 6.—But the moſt remarkable inſtance of the penetrability of the electric light, is that related by Dr Prieſtley. "I laid a chain (ſays he), which was in contact with the outſide of a jar, lightly on my finger, and ſometimes kept it at a ſmall diſtance by means of a thin piece of glaſs. If I made the diſcharge at the diſtance of about three inches, the electric fire was viſible on the ſurface of the finger, giving it a ſudden concuſſion, which ſeemed to make it vibrate to the very bone; and when it happened to paſs on that ſide of the finger that was oppoſite the eye, the whole ſeemed, in the dark, perfectly tranſparent." 179

The following is Mr Cavallo's method of making this curious experiment.

Let the extremities of two wires, one of which proceeds from the outſide of a charged jar, and another from one branch of the diſcharging rod, be laid on a table at the diſtance of one-tenth of an inch from each other; then put the thumb juſt upon that interruption, preſſing it flat down. This done, bring the diſcharging rod in contact with the knob of the jar, and on making the diſcharge, the ſpark which neceſſarily happens under the thumb will illuminate it in ſuch a manner that the bone and the principal blood-veſſels may be eaſily diſcerned in it.

In this experiment the operator need not be afraid of receiving a ſhock; for the diſcharge of the jar paſſes from wire to wire, and only affects the thumb with a ſort of tremor, which is far from being painful.

We have before related Mr Hawkeſbee's experiment by which he rendered ſealing-wax tranſparent. Signior Beccaria effected the ſame by making an electric exploſion paſs between two plates of ſealing-wax, on which ſome braſs-duſt was ſprinkled. The whole was rendered perfectly luminous and tranſparent.

180 Spiral tube. *Exper.* 7.—Fig. 57. repreſents an inſtrument compoſed of two glaſs tubes CD, one within another, and cloſed with two-knobbed braſs caps A and B. The innermoſt of theſe has a ſpiral row of ſmall round pieces of tin-foil ſtuck upon its outſide ſurface, and lying at about one-thirtieth of an inch from each other. If this inſtrument be held by one of the extremities, and its other extremity be preſented to the prime conductor, every ſpark that it receives from the prime conductor will cauſe ſmall ſparks to appear between all the round pieces of tin-foil ſtuck upon the innermoſt tube; which in the dark affords a pleaſing ſpectacle, the tube appearing encompaſſed by a ſpiral line of fire.

Fig. 58. repreſents ſeveral ſpiral tubes placed round a board, in the middle of which is ſcrewed a glaſs pillar, and on the top of this pillar is cemented a braſs cap with a fine ſteel point. In this a braſs wire turns, having a braſs ball at each end, nicely ballanced on the wire. To make uſe of this apparatus, place the middle of the turning wire under a ball proceeding from the conductor, ſo that it may receive a ſucceſſion of ſparks from the ball; then puſh the wire gently round; and the balls in their relative motions will give a ſpark to each tube, and thereby illuminate them down to the board, which from its brilliancy and rapid motion, affords a moſt beautiful and pleaſing ſight.

181 Luminous word. *Exper.* 8.—The ſmall pieces of tin-foil may be ſtuck on a flat piece of glaſs ABCD, fig. 59. ſo as to repreſent various fanciful figures. Upon the ſame principle is the word LIGHT produced, in luminous characters. It is formed by the ſmall ſeparations of the tin-foil paſted on a piece of glaſs fixed in a frame of baked wood, as repreſented fig. 60. To uſe this, the frame muſt be held in the hand, and the ball G preſented to the conductor. The ſpark then will be exhibited in the intervals compoſing the word; from whence it paſſes to the hook at *h*, and thence to the ground by a chain. The brilliancy of this is equal to that of the ſpiral tubes.

Though many of the following experiments on electric light, may not with ſtrict propriety belong to this chapter, we ſhall relate them here for the ſake of uniformity.

182 Morgan's propoſitions on electric light. Mr G. Morgan, in the Philoſophical Tranſactions for 1785, has given a ſeries of propoſitions reſpecting the electric light, and illuſtrated them by experiments; we ſhall here give the ſubſtance of his paper nearly in his own words.

I. There is no fluid or ſolid body, in its paſſage through which the electric light may not be rendered luminous.

This propoſition has been fully illuſtrated by the foregoing experiments.

183 II. The difficulty of making any quantity of the electrical light viſible in any body, increaſes as the conducting power of that body increaſes.

Exper. 1.—In order to make the contents of a jar luminous in boiling water, a much higher charge is neceſſary, than would be ſufficient to make it luminous in cold water, which is univerſally allowed to be the worſt conductor.

Exper. 2.—There are various reaſons for believing the acids to be very good conductors; if, therefore, into a tube filled with water, and circumſtanced as has been already deſcribed, a few drops of either of the mineral acids are poured, it will be almoſt impoſſible to make the light viſible in its paſſage through the tube.

Exper. 3.—If a ſtring, whoſe diameter is one-eighth of an inch, and whoſe length is ſix or eight inches, is moiſtened with water, the contents of a jar will paſs through it luminouſly; but no ſuch appearance can be produced by any charge of the ſame jar, provided the ſame ſtring be moiſtened with one of the mineral acids. To the preceding inſtance we may add the various inſtances of metals which will conduct the electric power without any appearance of light, in circumſtances the ſame with thoſe in which the ſame force would have appeared luminous in paſſing through other bodies, whoſe conducting power is leſs.

184 III. That the eaſe with which the electric light is rendered viſible in any particular body, is increaſed by increaſing the rarity of the body. The appearance of a ſpark, or of the diſcharge of a Leyden phial, in rarefied air, is well known. But we need not reſt the truth of the preceding obſervation on the ſeveral varieties of this fact; ſimilar phænomena attend the rarefaction of ether, of ſpirits of wine, and of water.

Exper. 4.—Into the orifice of a tube, 48 inches long, and two-thirds of an inch in diameter, cement an iron ball, ſo as to bear the weight which preſſes upon it when the tube is filled with quickſilver, leaving only an interval at the open end, which contained a few drops of water. Having inverted the tube, and plunged the open end of it into a baſon of mercury, the mercury in the tube ſtood nearly half an inch lower than it did in a barometer at the ſame inſtant, owing to the vapour which was formed by the water. But through this rarefied water, the electrical ſpark paſſed as luminouſly as it does through air equally rarefied.

Exper. 5.—If, inſtead of water, a few drops of ſpirits of wine are placed on the ſurface of the mercury, phenomena, ſimilar to thoſe of the preceding experiment, will be diſcovered, with this difference only, that as the vapour in this caſe is more denſe, the electrical ſpark, in its paſſage through it, is not quite ſo luminous as it is in the vapour of water.

Exper. 6.—Good ether, ſubſtituted in the room of the ſpirits of wine, will preſs the mercury down ſo low as the height of 16 or 17 inches. The electric ſpark, in paſſing through this vapour, (unleſs the force be very great indeed), is ſcarcely luminous; but if the preſſure on the ſurface of the mercury in the baſon, be gradually leſſened by the aid of an air-pump, the vapour will become more and more rare, and the electric ſpark, in paſſing through it, more and more luminous.

Exper. 7.—It has not been diſcovered, that any vapour does eſcape from the mineral acids when expoſed in vacuo. To give them, therefore, greater rarity or tenuity, different methods are found neceſſary. With a fine camel-hair pencil, dipped in the ſulphuric, the nitric, or the muriatic acid, draw upon a piece of glaſs a line, about one-eighth of an inch broad. In ſome inſtances, you muſt extend this line to the length of 27 inches, and you will find that the contents of an electric battery, conſiſting of ten pint phials coated, will paſs over the whole length of this line with the greateſt brilliancy. If, by widening the line, or by laying on a drop of the acid, its quantity be increaſed in any particular part, the charge, in paſſing through that part, will not appear luminous. Water, ſpirits of wine, circumſtanced ſimilarly to the acids in the preceding experiments, will be attended with ſimilar, but not equal effects; becauſe, in conſequence of the inferiority of their conducting power, it will be neceſſary to make the line, through which the charge paſſes, conſiderably ſhorter.

185 IV. The brilliancy or ſplendour of the electric light, in its paſſage through any body, is always increaſed by leſſening the dimenſions of that body; that is, a ſpark, or the diſcharge of a battery, which we might ſuppoſe equal to a ſphere one quarter of an inch in diameter, will appear much more brilliant, if the ſame quantity is compreſſed into a ſphere one-eighth of an inch in diameter. This obſervation is the obvious conſequence of many known facts; if the machine be large enough to afford a ſpark, whoſe length is nine or ten inches, this ſpark may be ſeen ſometimes forming itſelf into a bruſh, in which ſtate it occupies more room, but appears very faintly luminous; at other times, the ſame ſpark may be ſeen dividing itſelf into a variety of ramifications, which ſhoot into the ſurrounding air. A ſpark, which in the open air cannot exceed one quarter of an inch in diameter, will appear to fill the whole of an exhauſted receiver, four inches wide and eight inches long: but in the former caſe it is brilliant, and in the latter it grows fainter and fainter, as the ſize of the receiver increaſes. This obſervation is further proved by the following experiments.

Exper. 8.—To an inſulated ball, four inches in diameter, fix a ſilver thread, about four yards long. This thread, at the end which is remoteſt from the ball, muſt be fixed to another inſulated ſubſtance. Bring the ball within the ſtriking diſtance of a conductor, and the ſpark, in paſſing from the conductor to the ball, will appear very brilliant; the whole length of the ſilver thread will appear faintly luminous at the ſame inſtant. When the ſpark is confined within the dimenſions of a ſphere, one-eighth of an inch in diameter, it will be bright; but when diffuſed over the ſurface of air which received it from the thread, it's light will be ſo faint as to be ſeen only in a dark room. If you leſſen the ſurface of air which receives the ſpark, by ſhortening the thread, it will not fail to increaſe the brightneſs of the appearance.

Exper. 9.—To prove that the faintneſs of the electric light in vacuo, depends on the enlarged dimenſions of the ſpace through which it is diffuſed; we have nothing more to do than to introduce two pointed wires into the vacuum, ſo that the fluid may paſs from the point of the one to the point of the other; when the diſtance between them is not more than the one-tenth of an inch, in this caſe we ſhall find a brilliancy as great as in the open air.

Exper 10.—Into a Torricellian vacuum, 36 inches long, convey as much air as will fill two inches only of the exhauſted tube if it were inverted in water; this quantity of air will afford reſiſtance enough to condenſe the light as it paſſes through the tube into a ſpark, 38 inches in length. The brilliancy of the ſpark in condenſed air, in water, and in all ſubſtances through which it paſſes with difficulty, depends on principles ſimilar to thoſe which account for the preceding facts.

V. That in the appearances of electricity, as well as in thoſe of burning bodies, there are caſes in which all the rays of light do not eſcape; and that the moſt refrangible rays are thoſe which eſcape firſt or moſt eaſily. The electrical bruſh is always of a purple or bluiſh hue. If you convey a ſpark through a Torricellian vacuum, made without boiling the mercury in the tube, the bruſh will diſplay the indigo rays. The ſpark, however, may be divided and weakened, even in the open air, ſo as to yield the moſt refrangible rays only. 186

Exper. 11.—To an inſulated metallic ball, four inches in diameter, fix a wire a foot and half long; this wire ſhould terminate in four ramifications, each of which muſt be fixed to a metallic ball half an inch in diameter, and placed at an equal diſtance from a metallic plate, which muſt be communicated by metallic conductors with the ground. A powerful ſpark, after falling on the large ball at one extremity of the wire, will be divided in it's paſſage from the four ſmall balls to the metallic plate. When you examine the diviſion of the ſpark in a dark room, you will diſcover ſome little ramifications, which will yield the indigo rays only: indeed at the edges of all weak ſparks, the ſame purple appearance may be diſcovered. You may likewiſe obſerve, that the nearer you approach the center of the ſpark, the greater is the brilliancy of its colour.

VI. That the influence of different media on electrical light, is analogous to their influence on ſolar light, and will help us to account for ſome very ſingular appearances. 187

Exper. 12.—Let a pointed wire, having a metallic ball fixed to one of its extremities, be forced obliquely into a piece of wood, ſo as to make a ſmall angle with the ſurface of the wood, and to make the point lie about one-eighth of an inch below the ſurface. Let another pointed wire, which communicates with the ground, be forced in the ſame manner into the ſame wood, ſo that its point likewiſe may lie about one-eighth of an inch below the ſurface, and about two inches diſtant from the point of the firſt wire. Let the wood be inſulated, and a ſtrong ſpark, which ſtrikes on the metallic ball will force its paſſage through the interval of wood which lies between the points, and appear as red as blood. To prove that this appearance depends on the wood's abſorption of all the rays but the red; when theſe points were deepeſt below the ſurface, the red only came to the eye through a priſm; when they were raiſed a little nearer the ſurface, the red and orange appeared; when nearer ſtill, the yellow; and ſo on, till, by making the ſpark paſs through the wood very near its ſurface, all the rays were at length able to reach the eye. If the points be only one-eighth of an inch below the ſurface of ſoft deal wood, the red, the orange, and the yellow rays will appear as the ſpark paſſes through it; but when the points are at an equal depth

Principles of Electricity illuſtrated by experiment.

depth in a harder piece of wood, (ſuch as box) the yellow, and perhaps the orange will diſappear. As a farther proof that the phenomena, thus deſcribed, are owing to the interpoſition of the wood, as a medium which abſorbs ſome of the rays, and ſuffers others to eſcape; it may be obſerved, that when the ſpark ſtrikes very brilliantly on one ſide of the piece of deal, on the other ſide it will appear very red. In like manner, a red appearance may be given to a ſpark which ſtrikes brilliantly over the inſide of a tube, merely by ſpreading ſome pitch very thinly over the outſide of the ſame tube.

Exper. 13.—If into a Torricellian vacuum, of any length, a few drops of ether are conveyed, and both ends of the vacuum are ſtopped up with metallic conductors, ſo that a ſpark may paſs through it; the ſpark in its paſſage will aſſume the following appearances. When the eye is placed cloſe to the tube, the ſpark will appear perfectly white; if the eye is removed to the diſtance of ſix or ſeven yards, the colour of the ſpark will be reddiſh. Theſe changes evidently depend on the quantity of medium through which the light paſſes, and the red light of a diſtant candle, or a beclouded ſun.

Exper. 14.—Dr Prieſtley long ago obſerved the red appearance of the ſpark when paſſing through hydrogen gas; but this appearance is very much diverſified by the quantity of medium, through which you look at the ſpark. When at a very conſiderable diſtance, the red comes to the eye unmixed; but if the eye is placed cloſe to the tube, the ſpark appears white and brilliant. In confirmation, however, of ſome of theſe concluſions, you muſt obſerve, that by increaſing the quantity of ſparks which are conveyed through any portion of hydrogen gas, or by condenſing that gas, the ſpark may be entirely deprived of its red appearance, and made perfectly brilliant. All weak exploſions and ſparks, when viewed at a diſtance, bear a reddiſh hue. Such are the exploſions which have paſſed through water, ſpirits of wine, or any bad conductor, when confined in a tube whoſe diameter is not more than an inch. The reaſon of theſe appearances ſeems to be, that the weaker the ſpark or exploſion is, the leſs is the light which eſcapes; and the more viſible the effect of any medium, which has a power to abſorb ſome of that light.

Chalk, oyſter-ſhells, together with thoſe phoſphoric bodies, whoſe goodneſs has been very much impaired by long keeping, when finely powdered, and placed within the circuit of an electrical battery; will exhibit, by their ſcattered particles, a ſhower of light; but theſe particles will appear reddiſh, or their phoſphoric power will be ſufficient only to detain the yellow, orange, and red rays. When ſpirits of wine are in a ſimilar manner brought within the circuit of a battery, a ſimilar effect may be diſcovered; its particles diverge in ſeveral directions, diſplaying a moſt beautiful golden appearance. The metallic oxides are, of all bodies, thoſe which are rendered phoſphoric with the greateſt difficulty; but even theſe may be ſcattered into a ſhower of red luminous particles by the electric ſtroke.

Principles of Electricity illuſtrated by experiment.

The following experiments are given by Mr Cavallo to illuſtrate the appearance of the electric light in rarefied air.

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Luminous conductor.

Exper. 1.—Fig. 61. repreſents a prime conductor, invented by Mr Henly, which ſhows clearly the direction of the electric power paſſing through it, from whence it is called the *luminous conductor* (*A*). The middle part EF of this conductor, is a glaſs tube about eighteen inches long, and three or four inches in diameter. To both ends of this tube the hollow braſs pieces FD, BE, are cemented air-tight, one of which has a point C, by which it receives the electric power, when ſet near the excited cylinder of the electrical machine, and the other has a knobbed wire G, from which a ſtrong ſpark may be drawn; and from each of the pieces FD, BE, a knobbed wire proceeds, within the cavity of the glaſs tube. The braſs piece FD, or BE, is compoſed of two parts, i. e. a cap F cemented to the glaſs tube, and having a hole with a valve, by which the cavity of the glaſs tube may be exhauſted of air; and the ball D, which is ſcrewed upon the cap F. The ſupporters of this inſtrument are two glaſs pillars faſtened in the bottom board H, like the prime conductor repreſented fig. 61. When the glaſs tube of this conductor is exhauſted of air by means of an air-pump, and the braſs ball is ſcrewed on, as repreſented in the figure, then it is fit for uſe, and may ſerve for a prime conductor to an electrical machine.

If the point C of this conductor is ſet near the excited cylinder of the machine, it will appear illuminated with a ſtar; at the ſame time the glaſs tube will appear all illuminated with a weak light; but from the knobbed wire, that proceeds within the glaſs from the piece FD, a lucid pencil will iſſue out, and the oppoſite knob will appear illuminated with a ſtar or round body of light, which, as well as the pencil of rays, is very clear, and diſcernible among the other light, that occupies the greateſt part of the cavity of the tube.

If the point C, inſtead of being preſented to the cylinder, be connected with the rubber of the machine, the appearance of light within the tube will be reverſed; the knob which communicates with the piece FD appearing illuminated with a ſtar, and the oppoſite with a pencil of rays.

If the wires within the tube EF, inſtead of being furniſhed with knobs, be pointed, the appearance of light is the ſame, but it ſeems not ſo ſtrong in this, as in the other caſe.

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Conducting glaſs tube.

Exper. 2.—Take a glaſs tube of about two inches diameter, and about two feet long; fix to one of its ends a braſs cap, and to the other a ſtop-cock, or a valve; then by means of an air-pump exhauſt it of air. If this tube be held by one end, and its other end be brought near the electrified prime conductor, it will appear to be full of light, whenever a ſpark is taken by it from the prime conductor; and much more ſo, if an electric jar be diſcharged through it.

This experiment may alſo be made with the receiver of an air-pump.—Take, for inſtance, a tall receiver, clean and dry, and through a hole at its top inſert a wire,

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(*A*) An inſtrument much like this conductor was ſome years ago invented by Dr Watſon, with which he made ſeveral original experiments upon the electric light.

Principles of Electricity illustrated by experiment.

wire, which muſt be cemented air-tight. The end of the wire, that is within the tube, muſt be pointed, but not very ſharp; and the other end muſt be furniſhed with a knob. Put this receiver upon the plate of the air-pump, and exhauſt it. If now the knob of the wire at the top of the receiver be touched with the prime conductor, every ſpark will paſs through the receiver in a denſe and large body of light, from the wire to the plate of the air-pump.

It muſt be obſerved, that when the air is very much rarefied, the electric light in it is leſs denſe, though more diffuſed; and contrarywiſe.

190 Aurora borealis.

Exper. 3.—Take a phial nearly of the ſhape and ſize of a Florence flaſk, ſuch as is repreſented at fig. 62.

Fix a ſtop-cock or a valve to its neck, and exhauſt it of air as much as it is poſſible with a good air-pump. If this glaſs be rubbed in the common manner uſed to excite electrics, it will appear luminous within, being full of a flaſhing light, which plainly reſembles the aurora borealis, or northern light. This phial may alſo be made luminous by holding it by either end, and bringing the other end to the prime conductor; in this caſe all the cavity of the glaſs will inſtantly appear full of flaſhing light, which remains in it for a conſiderable time after it has been removed from the prime conductor.

Inſtead of the above-deſcribed glaſs veſſel, a glaſs tube, exhauſted of air and hermetically ſealed, may be uſed, and perhaps with greater advantage. The moſt remarkable circumſtance of this experiment is, that if the phial or tube, after it has been removed from the prime conductor (and even ſeveral hours after its flaſhing light hath ceaſed to appear) be graſped with the hand, ſtrong flaſhes of light will immediately appear within the glaſs, which often reach from one of its ends to the other.

191 Viſible electric atmoſphere.

Exper. 4.—GI, fig. 63. repreſents the receiver with the plate of an air-pump. In the middle of the plate IF, a ſhort rod is fixed, having at its top a metal ball B nicely poliſhed, whoſe diameter is nearly two inches. From the top of the receiver another rod AD with a like ball A proceeds, and is cemented air-tight in the neck C; the diſtance of the balls from one another being about four inches, or rather more. If, when the receiver is exhauſted of air, the ball A be electrified poſitively, by touching the top D of the rod AD with the prime conductor or an excited glaſs tube, a lucid atmoſphere appears about it, which, although it conſiſts of a feeble light, is yet very conſpicuous, and very well defined; at the ſame time the ball B has not the leaſt light. The atmoſphere does not exiſt all round the ball A, but reaches from about the middle of it, to a ſmall diſtance beyond that ſide of its ſurface, which is towards the oppoſite ball B. If the rod with the ball A be electrified negatively, then a lucid atmoſphere, like the above deſcribed, will appear upon the ball B, reaching from its middle to a ſmall diſtance beyond that ſide of it, that is towards the ball A; at the ſame time the negatively electrified ball A remains without any light.

The operator in this experiment muſt take care not to electrify the ball A too much, as, in that caſe, a ſpark will paſs from one ball to the other, and the deſired effect will not be produced. A little practice, however, will render the experiment very eaſy and familiar.

This elegant experiment is the invention of Sig. Beccaria.

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Fig. 64. and 65. repreſent a curious appearance of the electric light. In fig. 65. the light is ſeen ſtreaming from a wire within the exhauſted receiver of an air-pump. If in this ſtate of things, the hand or a finger be applied to the external part of the receiver, part of the light will approach the finger, as repreſented in fig. 64.

The electric ſpark produces changes on moſt artificial colours.

193 Mr Cavallo's experiments on colours.

Mr Cavallo made ſeveral experiments on ſubſtances painted with various colours. They were occaſioned by his having obſerved that an electric ſpark ſent over the ſurface of a card, made a black ſtroke upon a red ſpot, from which he was induced to try the effect of ſending ſhocks over cards painted with different water colours. The force employed was generally about one foot and a half of charged ſurface; and the ſhocks were ſent over the cards while the latter were in a very dry ſtate.

“ Vermilion was marked with a ſtrong black track, about one tenth of an inch wide. This ſtroke is generally ſingle, as repreſented by AB, fig. 66. Sometimes it is divided in two towards the middle, like EF; and ſometimes, particularly when the wires are ſet very diſtant from one another, the ſtroke is not continued, but interrupted in the middle, like GH. It often, although not always happens, that the impreſſion is marked ſtronger at the extremity of that wire from which the electric ſparks iſſue, as it appears at E, ſuppoſing that the wire C communicates with the poſitive ſide of the jar; whereas, the extremity of the ſtroke, contiguous to the point of the wire D, is neither ſo ſtrongly marked, nor ſurrounds the wire ſo much, as the other extremity E.

“ Carmine received a faint and ſlender impreſſion of a purple colour.

“ Verdegriſe was ſhaken off from the ſurface of the card; except when it had been mixed with ſtrong gum-water, in which caſe it received a very faint impreſſion.

“ White lead was marked by a long black track, not ſo broad as that on vermilion.

“ Red lead was marked with a faint mark much like carmine.

“ The other colours I tried were orpiment, gamboge, ſap green, red ink, ultramarine, pruſſian blue, and a few others which were compounds of the above; but they received no impreſſion.

“ It having been inſinuated, that the ſtrong black mark, which vermilion receives from the electric ſhock, might poſſibly be owing to the great quantity of ſulphur contained in that mineral, I was induced to make the following experiment. I mixed together equal quantities of orpiment and flower of ſulphur; and with this mixture, by the help, as uſual, of very diluted gum-water, I painted a card; but the electric ſhock ſent over it left not the leaſt impreſſion.

“ Deſirous of carrying this inveſtigation on colours a little farther, with a particular view to determine ſomething relative to the properties of lamp black and oil, I procured ſome pieces of paper painted on both ſides with oil colours; and ſending the charge of two feet of coated glaſs over each of them, by making the interruption of the circuit upon their ſurfaces, I obſerved that the pieces of paper painted with lamp black, pruſſian blue, vermilion, and purple brown, were torn by the exploſion; but white lead, Naples yellow, Engliſh ochre, and verdigriſe, remained unhurt.

"The ſame ſhock ſent over a piece of paper painted very thickly with lamp black and oil left not the leaſt impreſſion. I ſent the ſhock alſo over a piece of paper unequally painted with purple brown, and the paper was torn where the paint lay very thin, but remained unhurt where the paint lay evidently thicker. Theſe experiments I repeated ſeveral times, and with ſome very little variation, which naturally produced different effects; however, they all ſeem to point out the following propoſitions.

"1. A coat of oil-paint over any ſubſtance, defends it from the effect of ſuch a ſhock as would otherwiſe injure it; but by no means defends it from any electric ſhock whatever.

"2. No one colour ſeems preferable to the others, if they are equal in ſubſtance, and equally well mixed with oil; but a thick coating does certainly afford a better defence than a thinner one.

"By rubbing the above mentioned pieces of paper, I find that the paper painted with lamp-black and oil is more eaſily excited, and acquires a ſtronger electricity, than the papers painted with the other colours; and perhaps on this account it may be, that lamp black and oil might reſiſt the ſhock ſomewhat better than the other paints.

"It is remarkable that vermilion receives the black impreſſion when painted with linſeed oil nearly as well as when painted with water. The paper painted with white lead and oil receives alſo a black mark; but its nature is very ſingular. The track when firſt made, is almoſt as dark as that marked on white lead painted with water; but it loſes its blackneſs, and in about an hour's time (or longer, if the paint is not freſh) it appears without any darkneſs; and when the painted paper is laid in a proper light appears only marked with a colourleſs track, as if made by a finger nail. I ſent the ſhock alſo over a piece of board, which had been painted with white lead and oil four years before, and the exploſion marked the black track upon this alſo; this track, however, was not ſo ſtrong, nor vaniſhed ſo ſoon, as that marked upon the painted paper; but in about two days time it alſo vaniſhed entirely.

CHAP. VIII. *Of the Mechanical Effects of the Electric Power.*

THE electric power in its paſſage through the air, drives light bodies before it.

194 Electric power drives light bodies before it.

Sig. Beccaria put a narrow piece of ſilver leaf between two plates of wax, laying it acroſs them, but ſo ſo that it did not quite reach one of the ſides. The diſcharge being made through this ſtrip of metal, by bringing a wire oppoſite to the ſilver at the place where it was diſcontinued; the ſilver was found melted, and part of it diſperſed all along the track that the electric ſpark took between the plates of wax, from the ſilver to the wire.

The following experiment ſhows the force of the electric exploſion in driving the particles of a metal into the pores of glaſs.

Take two ſlips of common window glaſs, about three inches long, and half an inch wide; put a ſmall ſlip of gold, ſilver, or braſs leaf, between them, and tie them together, or preſs them together between the boards of the preſs H, belonging to the univerſal diſcharger, leaving a little of the metallic leaf out between the glaſſes at each end; then ſend a ſhock through this metallic leaf, and the force of the exploſion will drive part of the metal into ſo cloſe a contact with the glaſs, that it cannot be wiped off, or even be affected by the common menſtrua which otherwiſe would diſſolve it. In this experiment the glaſſes are often ſhattered to pieces; but whether they are broken or not, the indelible metallic tinge will always be found in ſeveral places, and ſometimes through the whole length of both glaſſes.

Dr Prieſtley made the following experiments to aſcertain this remarkable property of the electric power.

He diſcharged frequent ſhocks both of a common jar, and another of three ſquare feet, through trains of braſs duſt, laid on a ſtool of baked wood, making interruptions in various parts of the train; and he always found the braſs duſt ſcattered in the intervals, ſo as to connect the two disjoined ends of the train; but then it was likewiſe ſcattered nearly as much from almoſt all other parts of the train, and in all directions.

When ſmall trains were laid, the diſperſion was the moſt conſiderable, and a light was very viſible in the dark, illuminating the whole circuit. It made no difference, in any of theſe experiments, which way the ſhock was diſcharged.

When he laid a conſiderable quantity of the duſt at the ends of two pieces of chain, through which the ſhock paſſed, at the diſtance of about three inches from one another, the duſt was always diſperſed over the whole interval, but chiefly laterally; ſo that the greateſt quantity of it lay in arches, extending both ways, and leaving very little of it in the middle of the path.

The Doctor then inſulated a jar of three ſquare feet, and upon an adjoining glaſs ſtand laid a heap of braſs duſt; and at the diſtance of ſeven or eight inches, a braſs rod communicating with the outſide of the jar. Upon bringing another rod communicating with the inſide, upon the heap of duſt, the heap was diſperſed in a beautiful manner, but not one way more than the other. It however, preſently reached the rod communicating with the outſide.

Making two heaps, about eight inches aſunder, he brought one rod communicating with the inſide upon one of them, and another rod communicating with the outſide upon the other. Both the heaps were diſperſed in all directions, and ſoon met; preſently after which the jar was diſcharged by means of this diſperſed duſt, in one full exploſion. When the two heaps were too far aſunder to promote a full diſcharge at once, a gradual diſcharge was made through the ſcattered particles of the duſt.

When one heap of duſt was laid in the centre of the ſtand, and the two rods were made to approach on each ſide of it, they each attracted the duſt from the ſide of the heap next to them, and repelled it again in all directions.

rections. When they came very near the heap, the diſcharge was made through it, without giving it any particular motion.

195 An experiment given by Mr Cavallo to prove the direction of the electric power in the diſcharge of a Leyden phial, will afford a good illuſtration of our preſent poſition.

Bend a card, length-ways, over a round ruler, ſo as to form a channel, or ſemicircular groove (B): lay this card upon the circular board E of the univerſal diſcharger, and in the middle of it put a pith-ball of about half an inch diameter; then at equal diſtances, about half or three quarters of an inch from the pith-ball, lay the two braſs knobs DD. The card being perfectly dry, and rather hot, if you connect, by means of a chain or otherwiſe, the outſide of a charged jar with one of the wires C, and bring the knob of the jar to the other wire C, you will obſerve, that on making the diſcharge, which muſt paſs between the knobs DD, and over the card, &c. the pith-ball is always driven in the direction of the electric power; i. e. it is puſhed towards that knob which communicates with the negative ſide of the jar.

It muſt be obſerved, that in this experiment the charge of the jar muſt be juſt ſufficient to paſs through the interval in the circuit; the card, or piece of baked wood, muſt be very dry and clean; and, in ſhort, the diſpoſition of the apparatus, and the performance of this curious experiment, require a degree of nicety that can only be obtained by practice. Without great precaution, it ſometimes fails; but when the operator has once got it to ſucceed, and follows exactly the ſame method of operating, he may be ſure that the event of the experiment will be conſtantly as above deſcribed.

196 *By the electric exploſion, paper, paſteboard, card, thin glaſs, and other non-conducting ſubſtances, may be perforated or broken.*

Exper. 1.—Take a card, a quire of paper, or the cover of a book, and keep it cloſe to the outſide coating of a charged jar; put one knob of the diſcharging rod upon the card, quire of paper, &c. ſo that between the knob and coating of the jar the thickneſs of that card or quire of paper only is interpoſed; laſtly, by bringing the other knob of the diſcharging rod near the knob of the jar, make the diſcharge, and the electric ſpark will pierce a hole (or perhaps ſeveral) quite through the card or quire of paper. This hole has a bur raiſed on each ſide, except the card, &c. be preſſed hard between the diſcharging rod and the jar. If this experiment be made with two cards inſtead of one, which however muſt be kept very little diſtant from one another, each of the cards, after the exploſion, will be found pierced with one or more holes, and each hole will have burs on both ſurfaces of each card. The hole, or holes, are larger or ſmaller, according as the card, &c. is more damp or more dry. It is remarkable, that if the noſtrils are preſented to it, they will be affected with a ſulphureous, or rather a phoſphoreal ſmell, juſt like that produced by an excited electric.

If, inſtead of paper, a very thin plate of glaſs, roſin, ſealing wax, or the like, be interpoſed between the knob of the diſcharging rod and the outſide coating of the jar, on making the diſcharge, this will be broken in ſeveral pieces.

If the exploſion is ſent over the ſurface of a piece of glaſs, this will be marked with an indelible track, which generally reaches from the extremity of one of the wires to the extremity of the other. In this manner, the piece of glaſs is very ſeldom broken by the exploſion. But Mr Henley diſcovered a very remarkable method to increaſe the effect of the exploſion upon the glaſs; which is by preſſing with weights that part of the glaſs which lies between the two wires (i. e. that part over which the ſhock is to paſs). He put firſt a thick piece of ivory upon the glaſs, and placed upon that ivory a weight at pleaſure, from one quarter of an ounce to ſix pounds: the glaſs in this manner is generally broken by the exploſion into innumerable fragments, and ſome of it is abſolutely reduced into an impalpable powder. If the glaſs is very thick, and reſiſts the force of the exploſion, ſo as not to be broken by it, it will be found marked with the moſt lively priſmatic colours, which are thought to be occaſioned by very thin laminæ of the glaſs, in part ſeparated from it by the ſhock. The weight laid upon the glaſs is always ſhook by the exploſion, and ſometimes it is thrown quite off from the ivory. This experiment may be moſt conveniently made with the univerſal diſcharger.

Exper. 2.—Place the extremities of two wires, one above and the other below a card, ſo as to be about an inch diſtance from each other, taking care that the card be kept ſteady. Then, make the charge of a Leyden phial paſs from one wire to the other, and it will be found, that a luminous track will paſs from the end of that wire which is connected with the poſitive ſurface of the phial, to the extremity of the other wire, where a hole will be perforated through the card.

This experiment, to which we ſhall have occaſion to refer hereafter, is by Mr Lullin of Geneva.

Mr Symmer made ſome experiments on the perforation of paper, which we ſhall mention here, as on them he grounded a principal argument in favour of that theory which he adopted, and of which we ſhall give an account hereafter.

Exper. 3.—A piece of paper covered on one ſide with Dutch gilding, and which had been left accidentally between two leaves in a quire of paper, in which a former experiment had been made, was found to have the impreſſion of two ſtrokes upon it, about a quarter of an inch from each other; the gilding was ſtripped off, and the paper left bare for a little ſpace in both places. In the centre of one of theſe places was a little

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(B) Inſtead of the card, a piece of baked wood may be cut in that ſhape, and painted over with lamp-black and oil; which will anſwer better than the card, it being much more ſteady, and not ſo liable to attract moiſture.

Principles of Electricity illuſtrated by experiment.

tle round hole, in the other only an indenture or impreſſion, ſuch as might have been made with the point of a bodkin.

Exper. 4.—In the middle of a paper book, of the thickneſs of a quire, Mr Symmer put a ſlip of tinfoil; and in another of the ſame thickneſs, he put two ſlips of the ſame ſort of foil, including the two middle leaves of the book between them. On paſſing the exploſion through the two different books, the following effects were produced. In the firſt, the leaves on each ſide of the tinfoil were pierced, while the foil itſelf remained unpierced; but at the ſame time, it might be perceived that an impreſſion had been made on each of its ſurfaces, at a little diſtance from one another; and ſuch impreſſions were ſtill more viſible on the paper, and might be traced, as pointing different ways. In the ſecond, all the leaves of the book were pierced, excepting the two that were included between the ſlips of tinfoil; and in theſe two, inſtead of holes, the two impreſſions in contrary directions, were viſible.

The following experiment ſhows how eaſily ſo hard a ſubſtance as glaſs, may be pierced by the electric ſpark. It is thus related by Mr Cavallo.

Exper. 5.—Let a glaſs tube of any diameter, and about five or ſix inches in length, be cloſed hermetically, or by means of ſealing-wax, at one end, and fill about half of it with olive oil; then ſtop the aperture of it with a cork, and let a wire paſs through the cork, and come ſo far within the tube, as to have its extremity below the ſurface of the oil. This end of the wire muſt touch the ſurface of the glaſs, for which purpoſe it muſt be bent nearly at right angles, which may be eaſily done before the cork is put upon the tube. Things being thus prepared, bend into a ring the other extremity of the wire, and ſuſpend it, with the tube hanging to it, to the wire at the end of the conductor. Then work the machine, and bring the knuckle of a finger or the knob of a wire near the outſide of the tube, juſt oppoſite to the extremity of the wire; the conſequence of which will be, that a ſpark will happen between the wire and the knuckle, which makes a hole through the glaſs.—By turning the wire about, or raiſing and lowering it, many holes may be ſucceſſively made in the ſame tube, after the manner above deſcribed.

Exper. 6.—Roll up a piece of ſoft tobacco-pipe clay in a ſmall cylinder, and inſert in it two wires, ſo that their ends without the clay may be about a fifth part of an inch from one another. If a ſhock be ſent through this clay, by connecting one of the wires with the outſide of a charged jar, and the other with the inſide, it will be inflated by the ſhock, i. e. by the ſpark, that paſſes between the two wires, and, after the exploſion, will appear ſwelled in the middle. If the ſhock ſent through it is too ſtrong, and the clay not very moiſt, it will be broken by the exploſion, and its fragments ſcattered in every direction. To make this experiment with a little variation, take a piece of the tube of a tobacco-pipe, about one inch long, and fill its bore with moiſt clay; then inſert in it two wires, as in the above rolled clay; and ſend a ſhock through it. This tube will not fail to burſt by the force of the exploſion, and its fragments will be ſcattered about to a great diſtance. If, inſtead of clay, the above-mentioned tube of the tobacco pipe, or a glaſs tube (which will anſwer as well), be filled with any other ſubſtance, either electric or non-electric, inferior to metal, on making the diſcharge, it will be broken in pieces with nearly the ſame force. This experiment is the invention of Mr Lane, F. R. S.

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Exper. 7.—Place within a common drinking-glaſs, nearly full of water, two knobbed wires, bent in ſuch a manner, as that their knobs may be within a little diſtance of each other in the water. Connect one of theſe wires with the outſide coating of a pretty large jar, and touch the other wire with the knob of it; on making the diſcharge, the exploſion which muſt paſs through the water between the two knobs, will diſperſe the water, and break the glaſs with a ſurpriſing violence. This experiment requires great caution.

Sig. Beccaria contrived a ſmall mortar, into which a drop of water was put, between the extremities of two wires which went through the ſides of the mortar, and a wooden ball was applied over the drop of water; then a charged jar being diſcharged through the wires of the mortar, and conſequently through the drop of water, rarefied the latter, and drove the ball out with conſiderable force. Mr Lullin produced a greater effect by making the diſcharge through oil inſtead of water.

Chap. IX. *Of the Methods of eſtimating the Degree of Accumulated Electricity in Jars and Batteries.*

197 The only method of aſcertaining the charge of a Leyden phial or of a battery, which we have hitherto mentioned, is that of obſerving the repulſive force of the charge on the ball of Henly's quadrant electrometer. But it was found (*Viae* 122) that this was not always a juſt criterion of the amount of the charge; as, even when the jar was inſulated, and conſequently could receive no charge, the index of the electrometer ſtill roſe as high as if the jar was fully charged. We ſhall now proceed to deſcribe two methods, which, particularly the laſt, are much leſs liable to error. The firſt depends on the following principle.

198 *The diſtance of the ball of a diſcharging rod from the knob of a charged phial or battery neceſſary to produce an exploſion, will be greater in proportion to the degree of accumulated electricity which the jar or battery has received.*

Exper.—Take a Leyden phial, into the knob of which is fixed a quadrant electrometer; communicate to it a ſmall charge, ſo that the index of the electrometer may point, we ſhall ſuppoſe, at 10°. In making the diſcharge, it will be found neceſſary to bring the ball of the diſcharging rod almoſt in contact with the knob of the jar. Now charge the jar to 20°, and it will be found that the exploſion will take place, when the ball of the diſcharging rod is at a greater diſtance from the knob of the jar, than before; and thus, by repeating the experiment with greater charges, it will be obſerved, that the diſtance neceſſary to produce an exploſion will increaſe nearly in proportion to the charge.

199 Lane's electrometer. On this principle Mr Lane conſtructed an electrometer, which has been found extremely uſeful, when it was required to diſcharge a jar or battery a number of times ſucceſſively, with the ſame charge. This inſtrument

ſtrument has been called Mr Lane's *diſcharging electrometer*.

The principal part of it conſiſted originally of a braſs ball about an inch and a half in diameter, ſcrewed to a graduated braſs rod, and adapted to a proper frame, ſo that it might be ſet at any required diſtance from the prime conductor of the knob of a Leyden phial. The chief uſe of this inſtrument is to allow a jar to diſcharge ſpontaneouſly through any proper circuit, without employing a diſcharging rod, or moving any part of the apparatus, and alſo to produce ſucceſſive exploſions nearly of the ſame ſtrength, as obſerved above. If, for example, the braſs ball be placed at the diſtance of about half an inch from the prime conductor, and a Leyden phial be ſo ſituated as to have its knob in contact with the prime conductor, while its outſide coating communicates with the ball of the electrometer, it is evident that the communication between the outſide and inſide of the jar, is interrupted only between the prime conductor and the braſs ball, which are half an inch aſunder; therefore, in charging the jar, when the charge is become ſo high as to ſtrike through half an inch of air, the jar will diſcharge ſpontaneouſly, and by keeping the braſs ball at the ſame diſtance from the prime conductor, and charging the jar ſucceſſively, the ſhocks will be nearly of the ſame ſtrength.

Plate CLXXXIX.

An electrometer of this kind, though not exactly like the original one, is now commonly uſed by the practitioners of medical electricity, and is delineated in fig. 67. of Plate CLXXXIX. It conſiſts of a glaſs arm D, which proceeds from the wire of the jar F, and to the extremity E of which a ſpring ſocket is cemented, through which a wire paſſes, which is furniſhed with a knob B, towards the knob A of the jar, and with an open ring C at its other extremity. Now, as this wire may be ſlid backwards and forwards, the knob B may be put at any required diſtance from the knob A, as far as the conſtruction of the inſtrument will allow. The wire BC is generally marked with diviſions which ſhew the diſtance of the two knobs, when the wire is ſo ſituated, as that the required diviſion coincides with the edge of the ſpring ſocket; as, for inſtance, one-tenth, or one quarter of an inch, &c. When the jar F is ſet againſt the prime conductor G, as repreſented in the figure, ſuppoſe that the ball B is ſet at the diſtance of one-tenth of an inch from the ball A, and that a wire be fixed from the electrometer's ring to the outſide coating of the jar, as ſhewn by the dotted line CK; then, when the machine is put in motion, the diſcharge of the jar, as ſoon as this becomes ſufficiently charged, will be made between the knobs AB, and through the wire CK; and it is evident that theſe diſcharges will be of the ſame ſtrength, as long as the diſtance between AB remains the ſame.

This inſtrument is ſubject to the following inconvenience, viz. that the force of the exploſion, after a time, roughens the ſurface of the braſs ball, and thus, for a reaſon to be explained hereafter, the inſtrument is uſeleſs, unleſs the poliſh of the ball be again renewed. It is alſo found that this inſtrument is not accurate in ſhewing the exact charge of a jar.

200 *The charge of a jar or battery may be moſt accurately determined by the weight which the repulſive force of the accumulated electricity is able to raiſe.*

Upon this principle Mr Brooke of Norwich conſtructed a very valuable electrometer, of which he has given a long and accurate account in his *Miſcellaneous Experiments*.

Our limits will not permit us to copy this long deſcription, for which we muſt therefore refer our readers to Mr Brooke's work. We have, however, the leſs reaſon to regret this omiſſion, becauſe we ſhall preſently deſcribe an inſtrument invented by the late Profeſſor Robiſon, which appears to us ſuperior to Mr Brooke's both in ſimplicity and utility.

Mr G. Adams has deſcribed an electrometer very ſimilar in principle to that of Mr Brooke, and we ſhall here copy his deſcription.

201 Electrometer ſimilar to Mr Brooke's.

"Fig. 68. and 69. repreſent an electrometer, nearly ſimilar to that contrived by Mr Brooke. The two inſtruments are ſometimes combined in one, or uſed ſeparately, as in theſe figures. The arms FH*fk*, fig. 69. when in uſe, are to be placed as much as poſſible out of the atmoſphere of a jar, battery, prime conductor, &c. The arm FH and the ball K are made of copper, and as light as poſſible. The diviſions on the arm FH are each of them exactly a grain. They are aſcertained at firſt by placing grain weights on a braſs ball which is within the ball L, (this ball is an exact counterbalance to the arm FH and the ball K when the ſmall ſlide *r* is at the firſt diviſion) and then removing the ſlide *r*, till it, together with the ball K, counterbalances the ball L and the weight laid on it.

A, fig. 69, is a dial-plate, divided into 90 equal parts. The index of this plate is carried once round, when the arm BC has moved through 90 degrees, or a quarter of a circle. That motion is given to the index by the repulſive power of the charge acting between the ball D and the ball B.

The arm BC being repelled, ſhews when the charge is increaſing, and the arm FH ſhews what this repulſive power is between two balls of this ſize in grains, according to the number the weight reſts at when lifted up by the repulſive power of the charge: at the ſame time the arm BC points out the number of degrees to which the ball B is repelled; ſo that by repeated trials, the number of degrees anſwering to a given number of grains, may be aſcertained, and a table formed from theſe experiments, by which means the electrometer, fig. 69. may be uſed without that of fig. 68.

Mr Brooke thinks that no glaſs, charged (as we call it) with electricity, will bear a greater force, than that whoſe repulſive power, between two balls of the ſize he uſed, is equal to ſixty grains; that in very few inſtances it will ſtand ſixty grains weight; and he thinks it hazardous to go more than 45 grains.

Hence, by knowing the quantity of coated ſurface, and the diameter of the balls, we may be enabled to ſay, ſo much coated ſurface, with a repulſion between balls of ſo many grains, will melt a wire of ſuch a ſize, or kill ſuch an animal, &c.

Mr Brooke thinks, that he is not acquainted with all the advantages of his electrometer; but that it is clear, it ſpeaks a language which may be univerſally underſtood, which no other will do; for though other electrometers will ſhew whether a charge is greater or leſs, by an index being repelled to greater or ſmaller diſtances, or by the charge exploding at different diſtances, yet the power of the charge is by no means aſcertained: but this electrometer ſhews the force of the

the repulſive power in grains; and the accuracy of the inſtrument is eaſily proved, by placing the weights on the internal ball, and ſeeing that they coincide with the diviſions on the arm FH, when the ſlide is removed to them.

202
Mr Brooke's experiments on on the force of batteries.

With his electrometer, Mr Brooke made a ſet of experiments, with a view to determine exactly the force of batteries of an inferior power, in melting fine metallic wires of different kinds. The following is the ſubſtance of theſe experiments.

1. With a battery of nine bottles, containing about 16 ſquare feet of coated ſurface, and charged to 32 grains of repulſion, a ſhock was eleven times ſent through a piece of ſteel wire twelve inches long and $\frac{1}{100}$th of an inch thick; the wire was ſhortened an inch and a half, being then about ten inches and a half long; by a twelfth ſhock, the wire was melted to pieces.

2. A ſhock from the ſame nine bottles charged to the ſame degree of repulſion, being ſent through a piece of ſteel wire, 12 inches long and $\frac{1}{170}$th of an inch thick, the firſt time melted the whole of it into ſmall globules.

3. A ſhock from the ſame nine bottles charged to the ſame degree, being ſent through a piece of *braſs* wire twelve inches long and $\frac{1}{170}$th of an inch thick, melted the whole of it, with much ſmoke, reſembling that from gunpowder; but the metallic part formed itſelf, in cooling, chiefly into concave hemiſpherical figures of various ſizes.

4. A ſhock from only eight of the bottles charged to the ſame degree, did but juſt melt twelve inches of ſteel wire $\frac{1}{170}$th of an inch thick, ſo as to fall into ſeveral pieces; theſe pieces in cooling formed themſelves into oblong lumps, joining themſelves to each other by a very ſmall part of the wire between each lump which was not melted enough to ſeparate, but appeared like oblong beads on a thread at different diſtances.

5. A ſhock from the ſame eight bottles, charged to the ſame degree, ſo perfectly heated twelve inches of *braſs* wire about $\frac{1}{170}$th of an inch in diameter, as to melt it, or at leaſt ſoften it ſo far as to make it fall down by its own weight, from the forceps by which it was held at each end, upon a ſheet of paper placed below to catch it, and when it fell down it was ſo perfectly flexible that, by falling it formed itſelf into a vermicular ſhape, and remained entire its whole length, which when it was put into the forceps was about 12 inches: but after the ſhock was paſſed through it, it ſagged ſo much as to be ſtretched by its own weight to almoſt fifteen inches, and by falling on the paper it was flattened throughout its whole length ſo much, that when it was examined by a magnifier of half an inch focus, it appeared five or ſix times as broad as it was thick.

6. A ſhock from nine bottles charged only twenty grains, was ſent through a piece of ſteel wire, of the ſame length and diameter as in the former experiments, and heated it ſufficiently to melt it, ſo that it ſeparated in ſeveral places; and the pieces were formed into beads ſtrung as in experiment 4.

7. A ſhock from the ſame nine bottles charged to twenty grains was ſent through ten inches of braſs wire $\frac{1}{170}$th of an inch diameter; the wire was heated red hot ſo as to render it very flexible, but it did not ſeparate. It was ſhortened, however, nearly three-eighths of an inch.

8. A ſhock from the ſame nine bottles charged to the ſame degree, being ſent a ſecond time through the laſt piece of wire, melted it aſunder in ſeveral places.

9. A ſhock from nine bottles charged to 30 grains, ſent through twelve inches of braſs wire $\frac{1}{170}$th of an inch in diameter, acted on it nearly as in experiment 5, except that it was ſeparated in two places, and the pieces when joined meaſured about ſixteen inches and a half long; it was perfectly flattened by its fall on the paper as before.

10. A ſhock from nine bottles charged to 30 grains, being ſent through eight inches and a half of braſs wire of the ſame diameter, wholly diſperſed it in ſmoke, and left nothing remaining to fall on the ſheet of paper placed below it.

11. A ſhock from twelve bottles charged to 20 grains ſent through ten inches of ſteel wire, $\frac{1}{100}$th of an inch in diameter, made it red hot, but did not melt it.

12. A ſecond charge, the ſame as the laſt, being ſent through the ſame piece of wire, heated it red hot as before, but did not cauſe it to ſeparate; the wire was now, however, ſhortened five-ſixteenths of an inch.

13. A ſhock from the ſame twelve bottles charged to 25 grains, being ſent through the ſame piece of wire, partly melted it into ſeveral pieces, and produced many globules of oxidated metal.

14. With 15 bottles charged to 25 grains, a ſhock was ſent through ten inches of ſteel wire $\frac{1}{100}$th of an inch in diameter, which melted it at the firſt time, and diſperſed a great part of it about the room.

15. A ſhock from the ſame 15 bottles charged to 20 grains, juſt melted ten inches of ſteel wire of the ſame diameter as before, ſo as to cauſe it to run into ſeveral beautiful globules, nearly as in experiment 13.

16. A ſhock of 15 bottles charged to 15 grains, being ſent through ten inches of ſteel wire of the ſame diameter as the laſt, made the wire barely red-hot; but ſhortened it one-tenth of an inch.

17. The laſt piece of wire having received a ſhock from 15 bottles charged to 12 and a half grains, was not made red-hot.

18. A ſhock from the ſame 15 bottles, charged to 25 grains, was ſent through the ſame piece of wire, and ſeemingly tore the wire into ſplinters.

19. Four bottles charged to 30 grains, juſt melted three inches of ſteel wire $\frac{1}{170}$th of an inch in diameter, ſo as to make it fall into pieces.

20. Five bottles charged to 25 grains, melted three inches of ſuch wire as the laſt into large beautiful globules.

21. With eight bottles charged to 15 grains, three inches of ſteel wire, $\frac{1}{170}$th of an inch in diameter, were melted as in the laſt experiment; indeed the appearance and effect were ſo nearly alike in both caſes, that the metal after both experiments might have been ſaid to be the ſame.

22. The force of ten bottles charged twelve grains and a half rather exceeded experiment 19, but ſcarcely came up to experiments 20 and 21.

23. Suſpecting ſomething wrong in experiment 19, Mr Brooke found, that though his bottles hitherto were as nearly of the ſame ſize as he could procure them,

them, yet ſome of them were a little larger than others, and, which was the caſe in experiment 19, one of the four was ſmaller than the other three; ſo that he repeated the experiment with four bottles more equal in ſize, charging them to 30 grains, and the fuſion was as perfect as in any.

24. A charge to 30 grains, with the laſt eight bottles, beautifully melted ſix inches of ſteel wire $\frac{1}{170}$th of an inch in diameter.

25. A ſhock from two bottles charged to 45 grains, was ſent through one inch of ſteel wire, of the ſame diameter as the laſt, but only changed its colour.

26. With three bottles charged to 40 grains, a ſhock ſent through one inch and a half of ſteel wire of the above diameter, diſperſed it all about the room.

27. Mr Brooke conſidering that a ſteel wire of $\frac{1}{100}$th of an inch in diameter, contains nearly twice the quantity of metal which is contained in the ſame length of wire of $\frac{1}{170}$th of an inch in diameter, took three inches of the former, and ſent through it a ſhock from ten bottles, charged to 25 grains. This ſhock melted it juſt as the ſhock from five bottles did in experiment 20.

28. With 20 bottles charged to 12 grains and a half, he melted three inches of ſteel wire of $\frac{1}{100}$th of an inch in diameter, exactly as in the foregoing experiment.

29. As a ſteel wire of $\frac{1}{80}$th of an inch diameter contains nearly twice the quantity of metal in the ſame length, as is contained in a ſteel wire of $\frac{1}{100}$th, or four times the quantity contained in a ſteel wire of $\frac{1}{170}$th of an inch diameter; it might from the foregoing experiments be expected, that 20 bottles charged to 25 grains would melt three inches of ſteel wire of $\frac{1}{80}$th of an inch in diameter: but on a great many trials he could not procure 20 bottles which would bear the diſcharge when charged to 25 grains; for at the diſcharge, there was always one or more bottles broken or perforated. He was now reduced to the neceſſity of being content with bottles of any ſize, that would bear the required charge of from one to three gallons each, or that contained from 150 to 300 or more ſquare inches of coated ſurface each, but all in vain. The only reſource left him, as he was not near a glaſshouſe, was to increaſe the quantity of ſurface and not to charge ſo high and to proportion the one to the other: it was therefore reſolved to adopt a third expedient, i. e. inſtead of employing about 36 ſquare feet of coating, he added a third, or twelve feet, which made it in all 48 feet; and inſtead of charging to 25 grains, or rather 24 for the ſake of a more eaſy diviſion by three, he annulled one-third of the charge, leaving ſixteen grains, and thus he ſucceeded perfectly well; for by 48 feet of coated ſurface charged to 16 grains, three inches of ſteel wire $\frac{1}{80}$th of an inch in diameter were as curiouſly melted as in any of the former experiments.

Theſe bottles, thus broken in large diſcharges, ſeem always to break or to be perforated nearly in the thinneſt, but never in the thickeſt place, which ſhows the neceſſity of the glaſs being of a conſiderable thickneſs.

30. As in experiments 19. and 20. where the coated ſurface in the former is but half the quantity of that in the latter, and the former is charged to 30, and the latter to 15 grains, to know how high 48 feet of coating muſt be charged to produce the ſame effect exactly: and as the coating in four bottles, conſiſting of a little more than ſix feet and a half, is contained in 48 feet a little more than ſeven times; ſo Mr Brooke tried, by charging 48 feet only to a little more than four grains, or only about one-ſeventh part ſo high, as four times ſeven is 28; that is, but two leſs than 30: and this had exactly the ſame effect on the wire, which was $\frac{1}{170}$th of an inch in diameter, and three inches long, as it had upon the former.

31. As the laſt experiment agreed ſo exactly with experiments 19. and 20. the next thing tried was to ſee the effect of 48 feet of coated ſurface charged to a little more than four grains upon ſix inches of ſteel wire, the ſize of the laſt; this was made very faintly red.

32. By a repetition of the laſt experiment, with the ſame length of the ſame wire, to ſee how often the ſame charge might be ſent through it without melting it, and to obſerve the appearance of the wire after each ſhock, he found that by the eighth ſhock it was melted into ſeveral pieces. After the firſt ſhock, the redneſs produced became leſs every time, even the laſt time, when it was ſeparated. By the firſt ſhock, though made little more than fairly red, the wire became ſo flexible, that by a ſmall addition to its own weight, it ſeemed to become almoſt perfectly ſtraight when cooled: at about the third or fourth ſhock it began to aſſume a zig-zag appearance; after the ſixth ſhock the ſurface of it appeared rough; after the ſeventh ſhock the ſurface was very roughly ſcorified or ſcaly; and ſome of the ſcales had fallen upon a piece of white paper placed at about half an inch diſtance below it. The eighth ſhock melted it in three places; and at theſe places where the angles appeared the ſharpeſt or moſt acute, a great number of the ſcales were driven off about the paper, and appeared as in experiment 18; ſome of them were almoſt one-tenth of an inch long, and ſome of them about a third or fourth part of the diameter of the wire in breadth, and very thin; after the ſeventh ſhock it was ſhortened ſeven-ſixteenths of an inch; the wire was $\frac{1}{170}$th of an inch in diameter.

33. Repeating experiment 31. again with the ſame length of wire of the ſame diameter, and the ſame battery charged to the ſame degree, in order to obſerve the method of the wire ſhortening, having fixed an inſulated gage parallel to it and at the diſtance of about a quarter of an inch from it: after the firſt ſhock, which made the wire fairly red, (holding it fixed at one end, that the ſhortening might appear all at the other, which was held ſo that it might either contract or dilate) he obſerved, that it ſhortened conſiderably as it cooled; repeating the ſhock, it did the ſame, and ſo on till it was melted, which was by the eighth ſhock, as before. At the inſtant when the ſhock paſſed through the wire, it appeared to dilate a little; and after it was at the hotteſt, it gradually contracted after every ſtroke, as it cooled, about one-ſixteenth of an inch each time; the dilatation was ſo very trifling, as to bear but a very ſmall proportion to its contraction, and ſometimes it was doubtful whether or not it dilated at all; but after all the obſervations it appeared oftener to dilate, than not.

34. The ſame 48 feet, negatively charged to a little more than four grains, melted three inches of ſteel wire $\frac{1}{170}$th of an inch in diameter, the ſame as the poſitive charge did in experiment 30.

35. The ſame battery of 48 feet of coated ſurface, charged

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charged to a little more than eight grains, melted three inches of ſteel wire, $\frac{1}{100}$th of an inch in diameter. This is very nearly in proportion to experiment 27, but here the charge was negative, and Mr Brooke ſays the the fuſion was the moſt pleaſing he had hitherto had; which he attributes to the charge having been probably ſo well adjuſted as to be exactly ſufficient to melt the wire and no more: the heat remained for the longeſt time, and the fuſed metal ran into the largeſt globules; probably the long continuance of the heat, was owing to the charge being juſt ſufficient, and to the ſize of the lumps into which the fuſed metal was formed.

36. This was a repetition of experiment 1. with twelve inches of ſteel wire $\frac{1}{170}$th of an inch in diameter, but with this difference, that as then only nine bottles were employed, containing about ſixteen feet of coated ſurface, charged to 32 grains, he here uſed 18 bottles containing about 32 ſquare feet of coating charged to only 16 grains. This was done to obſerve the progeſs of the deſtruction of the wire, as in experiment 32. as well as to prove the ſimilarity of the effect. The wire being the ſame ſize, ſort of metal, and length, as recited juſt above; the firſt ſhock made it red-hot throughout its whole length attended with ſmoke and ſmell, changed its colour to a kind of copperiſh hue, and ſhortened it conſiderably; the ſecond ſhock made it of a fine blue, but it did not appear red, and ſhortened it more; at the third ſhock it aſſumed a zig-zag appearance, many radii were very viſible at the bendings, and the wire continued to ſhorten till the eleventh ſhock, when one of the bottles in the ſecond row of the battery was ſtruck through: the fracture was covered over with common cement, and its place ſupplied by changing place with one in the third row, ſuppoſing the mended one to be the weakeſt; and with the battery in this ſtate he made the twelfth ſhock, which ſeparated the wire as in experiment 1. but ſhortened it only one inch.

37. A ſhock from 48 feet of coated ſurface, charged to eight grains, ſent through three inches of copper wire $\frac{1}{170}$th of an inch in diameter, ſeven times, gave it the zig-zag appearance, but did not make it much ſhorter; the eighth ſhock ſeparated it at one end cloſe to the forceps which held it, but it did not appear to be made at all ſenſibly red-hot, notwithſtanding it muſt have been often ſo at the place where it was melted; which ſpace was ſo very ſmall as barely to be perceptible, like as when a point is ſet upon any flat ſurface of iron, and a ſhock from a pound phial ſent through, both the point and flat ſurface where the point reſted, if examined with a magnifying glaſs, will be found to have been melted, and a ſpeck may be ſeen; but the redneſs of the metal will ſcarcely be viſible.

38. A ſhock from 48 feet, charged to 16 grains, was ſent through ſix inches of lead wire $\frac{1}{50}$th of an inch in diameter, and melted it into many pieces.

39. A ſhock from 48 feet, charged to 15 grains, was ſent through ſix inches of wire like the laſt, which did not ſeparate it, but made it ſmoke.

40. A ſhock like the laſt, was ſent through the ſame piece of wire a ſecond time, and melted it into ſeveral pieces.

The law by which wires reſiſt deſtruction, in proportion to the diameter of the wire, does not ſeem to be nearly ſo equable, in the lead as in the ſteel wire. For a charge of four grains, in experiment 34. melted three inches of lead wire $\frac{1}{60}$th of an inch in diameter; but it took a charge of about three times that power, to deſtroy three inches of lead wire $\frac{1}{50}$th of an inch in diameter; which is about double the quantity of metal in the ſame length as in that of $\frac{1}{60}$th of an inch in diameter. Thus, it is eaſy to find what different reſiſtance a wire of any of the preceding metals, of equal ſize and length, will make to the electrical ſtroke.

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The length of the electric circuit, in which the different wires were placed, in the foregoing experiments, from the neareſt part of the inſide to the neareſt part of the outſide of the battery, excluſive of the length of the ſaid wires, was about eight feet.

41. Two gentlemen coming to ſee a piece of wire melted by electricity, Mr Brooke proceeded to ſhew it them, by fixing twelve inches of ſteel wire $\frac{1}{170}$th of an inch in diameter, and then (ſuppoſing the electrometer, and all other things ready placed), to charge the battery, but the electrometer did not move: nevertheleſs, he continued charging as he ſuppoſed; but ſtill the electrometer remained as it was, although he had been charging much longer than would have been neceſſary, contrary to his deſign, which was to take a ſmall wire, that a ſmaller charge might be ſufficient. Having been charging a long time, Mr Brooke left off to look about the apparatus, in order to ſee if all was right: as he was looking he found there was no communication between the battery and the electrometer, and he heard a ſlight crackling in the battery which convinced him that it was charged. Accordingly he made the diſcharge, expecting nothing unuſual; but the wire was diſperſed ſeemingly in a very violent manner. The report was ſo very loud that their ears were ſtunned, and the flaſh of light ſo very great, that Mr Brooke's ſight was quite confuſed for a few ſeconds.

203 Cuthbertſon's compound electrometer.

Mr Cuthbertſon has lately contrived an electrometer, which poſſeſſes all the advantages of Mr Brooke's, added to thoſe of Lane and Henly, with which he has ingeniouſly combined it.

This valuable inſtrument is thus deſcribed by the inventor.

The electrometer is repreſented in Plate CLXXXIX. N° 2. fig. 70. GH is a long ſquare piece of wood, about 18 inches long, and ſix inches broad, in which are fixed three glaſs ſupports, DEF, mounted with braſs balls, *a b c*. 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 to the top of F; and the ſame ball has a hole at the top, of about one-half inch diameter, correſponding with the inſide of the tube. AB is a ſtraight braſs wire, with a knife-edged centre in the middle, placed a little below the centre of gravity, and equally balanced with a hollow braſs ball at each end, the centre, or axis, reſting upon a proper ſhaped piece of braſs fixed in the inſide of the ball *c*; that ſide of the hemiſphere towards *c* is cut open, to permit the end *c* A of the balance to deſcend till it touches the ball *a*, and the upper hemiſphere C is 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;* a number of ſuch pins are commonly made to each electrometer of different weights; (c) *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 a pin *i*, of any ſmall weight, 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 before, 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, for which purpoſe it was invented, 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 (D): *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 part of the inſtrument does not act till the battery has received its required charge.

If this inſtrument be examined with attention, it will be found to conſiſt of three electrometers; and anſwers three different purpoſes, namely, a Henly's electrometer, Lane's diſcharging electrometer, and Brooke's ſteelyard electrometer; the firſt not improved, but the two laſt, which were very defective when firſt invented, I flatter myſelf are here brought to perfection. As the only uſe of Henly's electrometer to this inſtrument is, as I have ſaid before, to ſhew, by its continuing to increaſe in divergency, that the battery continues to receive a ſtill ſtronger charge, it required no improvement; but Lane's electrometer, in its primitive ſtate, could by no means anſwer the required purpoſe for batteries, becauſe the ball intended to diſcharge the battery, was neceſſarily placed ſo near to the ball of the battery, that duſt and fibrous particles were always attracted by and adhered between the two balls, ſo as to retard the charging, and often render a high charge impoſſible: whereas, in this, they are placed at four inches aſunder; and when the deſired height of charge is obtained, and not before, the ball of the electrometer moves of itſelf nearer to the ball which is connected with the outſide of the battery, and cauſes a diſcharge. The defects in Brooke's ſteelyard electrometer were, 1ſt, that it could not cauſe a diſcharge; and 2dly, the difficulty of obſerving the firſt ſeparation of the balls cauſed great error. If it were not placed in an advantageous light (which the nature of the experiments could not always permit), it would not be ſeen, without the attention of an aſſiſtant, which is ſometimes unpleaſant, and cannot always be commanded. But the inſtrument which I have deſcribed, requires no attention or aſſiſtance; for as ſoon as the ſeparation takes place between B and *b*, the ball A deſcends, and diſcharges the battery of itſelf.

By this combination and improvements, we poſſeſs in the preſent inſtrument all that can ever be required of an electrometer; namely, 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 *.

204 Col. Haldane's mode of meaſuring the charge of a battery.

With this electrometer Lieutenant Colonel Haldane has made ſome very ingenious experiments to determine the *exact* charge of a battery required to produce certain changes in wires of the ſame kind. His method of eſtimating the force of the charge is by the number of exploſions that it is capable of producing in a jar connected with the outſide coating of the battery. Thus, if the battery while charging produces three exploſions of the jar, he ſays, it has received three *meaſures* of electricity.

Mr Cuthbertſon having obſerved that when he breathed into a jar, it was thus rendered capable of receiving a higher charge, made the following experiments to aſcertain the effect of ſuch increaſed charge.

205 Breathing into a jar makes it bear a higher charge.

Exper. 1.—Prepare the electrometer in the manner ſhewn in the plate, with the jar M annexed, which contains about 168 ſquare inches of coating (E): put into B the pin, marked 15; 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.

Exper.

* *Nicholſon's Journ.* 4to vol. ii. p. 528.

(c) Inſtead of the pins, which were found inconvenient, Mr Cuthbertſon has lately conſtructed his electrometer with a ſliding piece of braſs, ſo adapted to the arm of the balanced wire, as by ſliding nearer to, or farther from the centre of gravity to denote proportional weights.

(D) 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 thance to the outſide of the battery, as is repreſented by the line N.

(E) Take out the pin in B, and obſerve whether the ball B will remain at reſt upon *b;* if uot turn the adjuſting ſcrew at C' till it juſt remains upon A.

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Exper. 2.—Put into the tongs eight inches of the ſame ſort of wire as before, hang one pair of tongs to the hook *m*, and apply the other to the wire which forms the outſide communication: take out the pin in B, and put in its ſtead one marked 30; all the other part of the apparatus remaining as before, and the uncoated part of the jar being previouſly cleaned and dried: the machine being then put in motion, the jar and electrometer will charge, as is ſhewn by the riſing of the index as before; but as ſoon as the jar has received a greater quantity of electric power than before, a ſpontaneous exploſion will happen without affecting the balls B *b*, becauſe the diſcharge will have paſſed along the uncoated part of the jar from the inſide coating to the outſide: whence it follows, that, while the jar remains in that clean ſtate, it is incapable of receiving a charge high enough to affect the balls, or even a higher charge than it had received in the firſt experiment. Let the uncoated part of the jar be therefore rendered, in a ſlight degree, damp; which is eaſily done, by breathing into the inſide, through a glaſs tube; put the machine in motion, and no ſpontaneous exploſion will happen, but the balls B *b* will repel, as in the firſt experiment, and the diſcharge will happen from A to *a*, and paſs through the wire placed in the circuit; and though it was eight inches, it will be fuſed in the ſame degree as two inches in the laſt experiment, namely, the wire ſeen red hot the whole length, and then fall into balls.

Very different degrees of fuſion are cauſed by electric diſcharges, which may cauſe great miſtakes, if not well attended to. It is proper to adhere to the degree above-mentioned, and particular care ought to be taken to lay the wire, intended for fuſion, ſtraight, without any bendings or angles in it. The wire uſed in the two laſt experiments, was that which is commonly called watch-pendulum wire, which is flatted; and as it approaches very near to ſuch a ſharp edge as might be ſuppoſed to affect the experiment, by permitting a diſſipation of the electric fluid in its paſſage, round wires were tried, and the reſult was the ſame.

206
Robiſon's comparable electrometer.

The late Dr Robiſon contrived an electrometer on ſimilar principles with that of Mr Brooke, but much ſuperior to it in ſimplicity of conſtruction, and not inferior to any which have been invented in point of accuracy.

Plate CLXXXIX. N° 2.

Fig. 71. exhibits a front view of this inſtrument, which is thus conſtructed. A poliſhed braſs ball A, a quarter of an inch in diameter, is fixed on the point of a common needle about three inches long, and as ſlender as can be procured of that length. On the other end of the needle is fixed a ball of *amber*, glaſs, or other ſolid non-conducting ſubſtance, of about half an inch or three-quarters of an inch in diameter. This ball is fixed in ſuch a way as that the needle does not quite reach to its ſurface, though the ball F muſt be completely perforated. From the electric ball there paſſes a ſlender glaſs rod, F, E, L, bent at right angles at E, ſo that the part FE is about three inches long, and the other extremity L is immediately oppoſite to the centre of the ball A. A piece of amber C, cut ſo as to have two parallel cheeks, is fixed on the extremity L of the glaſs rod. For the principal part of the inſtrument, a ſtrong dry ſilk thread is to be prepared by holding it perpendicular in melted ſealing-wax, till it ſhall be fully penetrated by the wax, ſo as to retain a thin coating of it. The thread, thus coated, muſt be kept extended, ſo that it may be quite ſtraight, and it muſt be made perfectly ſmooth by holding it before a clear fire and rolling it on a ſmooth plane. It is then to be paſſed through a ſmall cube of amber, that has two holes drilled in two of its oppoſite faces, perpendicularly about half way to the ſtalk. By theſe holes the cube is ſuſpended, ſo as to move readily, on two fine braſs pins, between the cheeks of the piece of amber at L. The waxed thread is about ſix inches long, and is equally divided by the amber cube. To one end of it, B, is fixed a ball of ſome conducting ſubſtance, as of very thin poliſhed metal, or gilt and burniſhed cork, a quarter of an inch in diameter. The other extremity, D, paſſes through a cork ball, ſo as to move with ſome friction.

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This part of the inſtrument is ſo conſtructed, that when FE is perpendicular to the horizon, and the ſtalk BD, with its balls, is allowed to hang freely, the ball B juſt touches the ball A. This poſition is repreſented in fig. 72.

The ball F is fixed to one end of a glaſs rod FI made to paſs perpendicularly through the centre of a graduated circle GHO, and furniſhed at its other extremity I with a knobbed handle of box wood. HK is the ſtand of the electrometer, in the head of which is a hole in which the rod FI moves ſmoothly but not eaſily. Farther, there is adapted to the glaſs rod FI an index NH that turns round it. This index is ſo placed as to be parallel to a line LA drawn through the centre of the ball A. Now, as the circle is divided into 360 degrees, 0 being marked above and 90 on the right hand; the index will point out the angle which the line LA makes with the vertical line. It is convenient to have another index on the rod FI turning ſtiffly round it, and extending conſiderably beyond the circle.

The method of uſing this inſtrument will be ſhewn when we ſpeak of the law of electric action in the next part.

Chap. X. *Of the Electrophorus.*

207
Deſcription of the electrophorus.

The electrophorus is an inſtrument invented by Signior Volta of Como. It generally conſiſts of two parts; a round plate of metal, or of wood, made perfectly free from points and edges, and covered with tin-foil; as A fig. 73: and another circular plate of any conducting ſubſtance covered with a coating of ſome reſinous electric, generally of lac diſſolved in alcohol, melted ſealing-wax, pitch, or of ſulphur; as B. The firſt plate is furniſhed with a glaſs handle, or with ſilk ſtrings, ſo that it may be occaſionally inſulated: to this plate Volta has given the name of *Scudo*.

Sometimes the apparatus is made in *three* parts, i. e. the reſinous electric is formed into a cake independent of the plate B, and this is the moſt convenient method for experiment. To theſe three parts Dr Robiſon has given the following names; viz. the reſinous electric he calls the *cake*, the plate B, the *ſole*, and the plate A the *Cover*; and theſe names we ſhall adopt for the ſake of convenience. For the purpoſe of exhibiting the appearances which we are about to deſcribe in the moſt *brilliant* manner, the ſeveral parts may be made very thin in proportion to their circumference; but for illuſtrating the theory

theory of the inſtrument, which we ſhall explain in the following part, they ſhould be made of conſiderable thickneſs. The *ſole* ſhould be provided with an inſulating ſtand.

The general appearances which have been obſerved with this apparatus may be reduced to the following heads.

1. If the *cake*, after being juſt formed, be ſuffered to remain on the *ſole*, till it be perfectly cool and hard, while the *ſole* is *inſulated;* on examination the whole will be found negatively electric, and on applying the finger to any part of it, eſpecially the *ſole*, a ſpark is produced. If the apparatus be now ſuffered to remain at reſt, its electricity gradually becomes weaker, and at length entirely diſappears. It may, however, be again produced by rubbing the *cake* with a piece of new flannel, or, what is better, a piece of hare or mole ſkin with the fur on, made dry and warm. If after the cake has been thus *excited*, the *cover* be placed on it, by means of its inſulating handle, and if it be again lifted off, *without being touched*, no electricity whatever can be obſerved in the cover.

2. If, however, the cover while in contact with the cake, be touched with the finger, a ſmart pungent ſpark will be obtained from the cover; and if, while the finger touches the cover, the thumb is placed upon the ſole, a ſenſible ſhock will be felt between the finger and thumb.

3. After the above ſpark or ſhock has been obtained, the electricity of the electrophorus diſappears, and the apparatus is ſaid to be dead; no ſigns of electricity appearing in either ſole or cover, ſo long as the latter remains in contact with the cake.

4. But if the cover be raiſed to ſome diſtance from the cake, and in a direction parallel to it, and if the cover be touched while held in this poſition, a ſmart ſpark will appear between it and the finger, and will even ſtrike to ſome diſtance. This ſpark will be more remarkable, if obtained from the upper ſurface of the cover, eſpecially from its edge, which, if it has not been well rounded, will even throw off ſparks into the air. The ſpark received from the cover under theſe circumſtances, is however, not ſo pungent as that mentioned in N° 2, reſembling a ſpark from any electrified conductor.

5. When the cover is thus raiſed from the cake, the former is found *poſitively* electrified, and the latter, as before, *negatively.*

6. But the electricity of both cover and cake, while in contact, is *negative.*

7. The appearances above deſcribed may be repeated for a conſiderable time, with apparently undiminiſhed vivacity, without re-exciting the cake by friction; the apparatus has been obſerved to retain its electric power, even for ſeveral months. Hence it ſerves as a kind of electrical magazine, and may be repeatedly employed for charging jars, either *poſitively*, by imparting to the jar the electric ſpark from the cover while raiſed from the cake; or *negatively*, by receiving the ſparks from the cover in contact with the cake. From this property of retaining the electric power for ſo long a time, Signior Volta denominated the apparatus *electrophorus*, or *elettroforo perpetuo.*

8. If, before placing the cover on the cake, the ſole has been inſulated, the ſame ſpark may be obtained from the cover, and the ſame ſhock may be felt on touching both cake and cover at the ſame time; but the ſpark, in this caſe, is by no means ſo pungent as that obtained when the ſole has not been inſulated.

9. If, when the ſole has been inſulated, the cover be again lifted to a conſiderable diſtance from the cake, the ſole will be found electrical, and its electricity will be the ſame as that of the cake, or *negative.*

10. If, after touching both ſole and cover, the cover be raiſed from the cake, by its inſulating handle, and again replaced upon the cake without being touched while ſeparate, the whole apparatus is found to poſſeſs no electricity.

11. If both ſole and cover be inactive after being joined, they will, when ſeparated, ſhow oppoſite electricities; the cover being electrified *poſitively* and the ſole *negatively.*

12. If both cover and ſole be rendered inactive while ſeparate, they will, when placed in contact, be found to poſſeſs the electricity oppoſite to that of the cake, i. e. they will together be in a ſtate of poſitive electricity.

208 Mr Cavallo's experiments on the electrophorus.

It is of little conſequence what ſubſtance forms the baſis to which the electric coating is applied; formerly a glaſs plate was employed, and this was coated with various reſinous electrics. Mr Cavallo, who made ſeveral experiments on the conſtruction and phenomena of the electrophorus, found that the moſt convenient electric was made with the ſecond ſort of ſealing-wax ſpread upon a thick glaſs plate. A plate made by him after this manner, the diameter of which was no more than ſix inches, was, when once excited, capable of charging a coated phial ſo ſtrongly, that by the exploſion, a card could be perforated; this phial might be charged ſeveral times ſucceſſively, without again exciting the plate. Sometimes the cover, when ſeparated from the plate, was ſo ſtrongly electrified, that it darted ſtrong flaſhes towards the table on which the electric plate was laid, and even into the air. "The power of ſome of my plates," ſays Mr Cavallo, "is ſo ſtrong, that ſometimes the electric plate adheres to the metal when this is lifted up; nor will they ſeparate even when the metal plate is touched with the finger, or other conductor.

"If, after having excited the ſealing-wax," continues he, "I lay the plate with the wax upon the table, and the glaſs uppermoſt, i. e. contrary to the common method, then, on making the uſual experiment of putting the metal plate on it, and taking the ſpark &c. I obſerve it to be attended with the contrary electricity; that is, if I lay the metal plate upon the electric one, and while in that ſituation touch it with an inſulated body, that body acquires the *poſitive* electricity, and the metallic, removed from the electric plate, appears to be negative; whereas it would become poſitive if laid upon the excited wax. This experiment, I find, anſwers in the ſame manner, if an electric plate is uſed which has the ſealing-wax coating on both ſides, or one of Mr Adams's, which has no glaſs plate.

"If the braſs plate, after being ſeparated from, be preſented

preſented with the edge towards the wax, lightly touching it, and thus be drawn over its ſurface, I find that the electricity of the metal is abſorbed by the ſealing-wax, and thus the electric plate loſes part of its power; and if this operation be repeated five or ſix times, the electric plate loſes its power entirely, ſo that a new excitation is neceſſary to revive it."

There is one part of Mr Cavallo's experiments upon the electrophorus, which by no means accords with the account of the phenomena given by us in Nos 8, 9, 10, 11, 12.

" If, ſays he, " inſtead of laying the electric plate upon a table, it be placed upon an electric ſtand ſo as to be accurately inſulated, then the metal plate ſet on it, acquires ſo little electricity that it can only be diſcovered by an electrometer.

" Upon an electric ſtand E fig. 73, I placed a circular tin plate, nearly ſix inches in diameter, which by a ſlender wire H, communicated with an electrometer of pith balls G, which was alſo inſulated upon the electric ſtand F. I then placed the excited electric plate D, of ſix inches and a quarter in diameter upon the tin plate with the wax uppermoſt, and on removing my hand from it, the electrometer G, which communicated with the tin plate, i. e. with the under ſide of the electric plate, immediately opened with negative electricity," &c. *.

It is ſomewhat extraordinary that ſo expert an electrician as Mr Cavallo, ſhould aſſert that an inſulated electrophorus ſhows weaker ſigns of electricity than one uninſulated; whereas, in fact, the electricity in the former caſe is generally ſtronger than in the latter, and always ſo ſtrong as to afford ſparks from ſome part of the apparatus.

209
Mr Morgan's experiments.

Mr G. Morgan has given us ſome valuable experimental obſervations on the *Inſulated Electrophorus.* His apparatus conſiſts of a rounded piece of wood, AB fig. 74. with ſmooth edges and covered with tin-foil, placed on an inſulating ſtand CD. On this board or ſole is placed the electric plate or cake; *a b* is a wire with a braſs ball from which are hung the electrometer balls *g h*. G repreſents the *ſcudo* or *cover*. After relating the uſual appearances produced by friction, he proceeds to deſcribe thoſe which ariſe from connecting the cake with oppoſite ſides of a Leyden phial.

" When the negative ſurface of a charged phial is placed on the excited ſurface, by bringing the hand into contact with the oppoſite ſide of the phial, a ſpark is inſtantly communicated, and the pith-balls *g* and *h*, ſeparate negatively.

If the phial be taken off, and the ſcudo placed in its room, no change is obſervable on the ſubſequent removal of the ſcudo, provided, that no communication has been formed between it and the ground. When ſuch a communication is formed, a charge is communicated, and the ſcudo and the balls are in oppoſite ſtates of electricity.

If the poſitive ſide of a Leyden phial be placed on the excited ſurface, the pith-balls ſeparate poſitively. It muſt be obſerved that theſe experiments are made with a reſinous ſubſtance.

The appearances of the pith-balls and ſcudo are materially varied, if the Leyden phial be applied to the electrophorus while the ſcudo is in contact with its excited ſurface. If the negative ſide of the phial be applied, and a ſpark be taken from the poſitive, the pith-balls immediately ſeparate negatively; but on taking up the ſcudo, they immediately cloſe, and as rapidly ſeparate again poſitively.

If after the phial is removed, the hand be applied to the ſcudo before it is raiſed, a ſmall ſpark ſtrikes into the hand; but on raiſing the ſcudo, the balls cloſe and ſeparate inſtantaneouſly, and give ſigns of poſitive electricity.—If the ſcudo and the braſs plate be connected, either by an inſulated or uninſulated diſcharging rod, the balls cloſe and ſeparate again, and the ſcudo, upon being raiſed, receives a vigorous negative ſpark.

It is obvious that in all the preceding experiments, the braſs plate continues unchangeably adherent to the lower ſurface, while the ſcudo only, or the conducting ſubſtance in connection with the upper ſurface, is immoveable. It is of importance that we ſhould know the conſequences of making both the metallic ſurfaces moveable.

But this is not an eaſy matter; it is very difficult to get a reſinous ſubſtance thin enough, and at the ſame time firm enough, for the purpoſe. The perfect laminæ of talc, which I have been able to procure, are too ſmall to be uſed with any ſatisfaction; I have therefore had recourſe to glaſs for the purpoſe. The reſult of my repeated trials is the following.

Having ſubſtituted a glaſs plate, about twelve inches in diameter, and one fourth of an inch thick, in the room of the reſinous ſubſtance, and having reſted it on a ground metallic plate, five inches in diameter, and well connected with the pith-balls *g* and *h*, I expoſed it to the ſparks of a conductor charged poſitively, and kept my hand at the ſame time in connexion with the wire *a b*. The plate took a conſiderable charge; its upper ſide was unequivocally poſitive, and its lower ſide negative. I placed the ſcudo on the glaſs thus charged, and approaching it with my hand, I received a ſpark. I then approached *a b* with my hand, and received another. By alternate approaches of this kind, four or five times repeated, the ſparks became weaker and weaker till they diſappeared; the ſcudo was then raiſed, and was ſtrongly negative; but the pith-ball, on the removal of the ſcudo, cloſed and ſeparated poſitively.

I then made the lower the upper ſurface; and placing the ſcudo upon it, formed the communication, as in the preceding part of the experiment; but upon being raiſed, the ſcudo was ſtrongly poſitive, and the balls negative.

But if, previous to the placing the ſcudo on the glaſs, the pith-balls be carefully diſcharged of all adherent electricity, both the upper and lower ſides of the glaſs will be charged with poſitive electricity, or will give ſigns of their being in the ſame ſtate at the ſame time.

It is obſervable that the ſucceſſion of electrics, in the preceding experiments ſeems to vary according to the priority of contact given to the wire or the ſcudo. But though this happens moſt frequently, yet ſuch anomalies take place as not to juſtify us in conſidering this ſingular connection of diverſities as by any means certain *".

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* *Cavallo's Electricity*, vol. ii.

* *Morgan's Lectures*, vol. i.

CHAP. XI. *Obſervations and Experiments on Excitation and Electrical Machines, with the deſcription of an Electrical Machine in which Silk is employed inſtead of Glaſs.*

210 Nicholſon's experiments on excitation. MR Nicholſon publiſhed in the Phil. Tranſ. for 1789, ſome valuable obſervations on the beſt means of excitation, which we ſhall here extract.

1. A glaſs cylinder was mounted, and a cuſhion applied with a ſilk flap, proceeding from the edge of the cuſhion over its ſurface, and thence half round the cylinder. The cylinder was then excited by applying an amalgamed leather in the uſual manner. The electricity was received by a conductor, and paſſed off in ſparks to Lane's electrometer. By the frequency of theſe ſparks, or by the number of turns required to cauſe ſpontaneous exploſion of a jar, the ſtrength of the excitation was aſcertained.

2. The cuſhion was withdrawn about one inch from the cylinder, and the excitation performed by the ſilk only. A ſtream of fire was ſeen between the cuſhion and the ſilk; and much fewer ſparks paſſed between the balls of the electrometer.

3. A roll of dry ſilk was interpoſed, to prevent the ſtream from paſſing between the cuſhion and the ſilk. Very few ſparks then appeared at the electrometer.

4. A metallic rod, not inſulated, was then interpoſed inſtead of the roll of ſilk, ſo as not to touch any part of the apparatus. A denſe ſtream of electricity appeared between the rod and the ſilk, and the conductor gave very many ſparks.

5. The knob of a jar being ſubſtituted in the place of the metallic rod, it became charged negatively.

6. The ſilk alone, with a piece of tin-foil applied behind it, afforded much electricity, though leſs than when the cuſhion was applied with a light preſſure. The hand being applied to the ſilk as a cuſhion, produced a degree of excitation ſeldom equalled by any other cuſhion.

7. The edge of the hand anſwered as well as the palm.

8. When the excitation by a cuſhion was weak, a line of light appeared at the anterior part of the cuſhion, and the ſilk was ſtrongly diſpoſed to receive electricity from any uninſulated conductor. Theſe appearances did not obtain when the excitation was by any means made very ſtrong.

9. A thick ſilk, or two or more folds of ſilk, excited worſe than a ſingle very thin flap. I uſe the ſilk which the milliners call Perſian.

10. When the ſilk was ſeparated from the cylinder, ſparks paſſed between them; the ſilk was found to be a weak negative, and the cylinder in a poſitive ſtate.

211 The ſilk flap the principal cauſe of excitation. The foregoing experiments ſhow that the office of the ſilk is not merely to prevent the return of electricity from the cylinder to the cuſhion, but that it is the chief agent in the excitation; while the cuſhion ſerves only to ſupply the electricity, and perhaps increaſe the preſſure at the entering part. There likewiſe ſeems to be little reaſon to doubt but that the diſpoſition of the electricity to eſcape from the ſurface of the cylinder is not prevented by the interpoſition of the ſilk, but by a compenſation after the manner of a charge; the ſilk being then as ſtrongly negative as the cylinder is poſitive; and, laſtly, that the line of light between the ſilk and cuſhion in weak excitations does not conſiſt of returning electricity, but of electricity which paſſes to the cylinder, in conſequence of its not having been ſufficiently ſupplied during its contact with the rubbing ſurface.

11. When the excitation was very ſtrong in a cylinder newly mounted, flaſhes of light were ſeen to fly acroſs its inſide, from the receiving ſurface to the ſurface in contact with the cuſhion, as indicated by the bruſh figure. Theſe made the cylinder ring as if ſtruck with a bundle of ſmall twigs. They ſeem to have ariſen from part of the electricity of the cylinder taking the form of a charge. This appearance was obſerved in a 9-inch and a 12-inch cylinder, and the property went off in a few weeks. Whence it appears to have been chiefly occaſioned by the rarity of the internal air produced by handling, and probably reſtored by gradual leaking of the cement.

212 State of the inſide of a cylinder during excitation determined. 13. With a view to determine what happens in the inſide of the cylinder, recourſe was had to a plate machine. One cuſhion was applied with its ſilken flap. The plate was 9 inches in diameter and $\frac{2}{10}$ths of an inch thick. During the excitation, the ſurface oppoſite to the cuſhion ſtrongly attracted electricity, which it gave out when it arrived oppoſite to the extremity of the flap: ſo that a continual ſtream of electricity paſſed through an inſulated metallic bow terminating in balls, which were oppoſed, the one to the ſurface oppoſite the extremity of the ſilk, and the other oppoſite to the cuſhion; the former ball ſhowing poſitive and the latter negative ſigns. The knobs of two jars being ſubſtituted in the place of theſe balls, the jar applied to the ſurface oppoſed to the cuſhion was charged negatively, and the other poſitively. This diſpoſition of the back ſurface ſeemed, by a few trials, to be weaker, the ſtronger the action of the cuſhion, as judged by the electricity on the cuſhion ſide.

Hence it follows, that the internal ſurface of a cylinder is ſo far from being diſpoſed to give out electricity during the friction by which the external ſurface acquires it, that it even greedily attracts it.

13. A plate of glaſs was applied to the revolving plate, and thruſt under the cuſhion in ſuch a manner as to ſupply the place of the ſilk flap. It rendered the electricity ſtronger, and appears to be an improvement of the plate machine.

14. Two cuſhions were then applied on the oppoſite ſurfaces with their ſilk flaps, ſo as to claſp the plate between them. The electricity was received from both by applying the finger and thumb to the oppoſite ſurfaces of the plate. When the finger was advanced a little towards its correſpondent cuſhion, ſo that its diſtance was leſs than between the thumb and its cuſhion, the finger received ſtrong electricity, and the thumb none; and, contrariwiſe, if the thumb were advanced beyond the finger, it received all the electricity, and none paſſed to the finger. This electricity was not ſtronger than was produced by the good action of one cuſhion applied ſingly.

15. The cuſhion in experiment 12. gave moſt electricity when the back ſurface was ſupplied, provided that ſurface was ſuffered to retain its electricity till the rubbed ſurface had given out its electricity.

213
No advantage gained by rubbing two ſides of the plate machine.

From the two laſt paragraphs it appears, that no advantage is gained by rubbing both ſurfaces; but that a well managed friction on one ſurface will accumulate as much electricity as the preſent methods of excitation ſeem capable of collecting; but that, when the excitation is weak, on account of the electric matter not paſſing with ſufficient facility to the rubbed ſurface, the friction enables the oppoſite ſurface to attract or receive it, and if it be ſupplied, both ſurfaces will paſs off in the poſitive ſtate; and either ſurface will give out more electricity than is really induced upon it, becauſe the electricity of the oppoſite ſurface forms a charge. It may be neceſſary to obſerve, that I am ſpeaking of the facts or effects produced by friction; but how the rubbing ſurfaces act upon each other to produce them, whether by attraction or otherwiſe, we do not here inquire.

214
Velocity neceſſary to produce the utmoſt degree of excitation.

16. When a cylinder is weakly excited, the appearances mentioned (par. 8.) are more evident the more rapid the turning. In this caſe, the avidity of the ſurface of the cylinder beneath the ſilk is partly ſupplied from the edge of the ſilk, which throws back a broad caſcade of fire, ſometimes to the diſtance of above 12 inches. From theſe cauſes it is that there is a determinate velocity of turning required to produce the maximum of intenſity in the conductor. The ſtronger the excitation, the quicker may be the velocity; but it rarely exceeds five feet of the glaſs to paſs the cuſhion in a ſecond.

17. If a piece of ſilk be applied to a cylinder, by drawing down the ends ſo that it may touch half the circumference, and the cylinder be then turned and excited by applying the amalgamed leather, it will become very greedy of electricity during the time it paſſes under the ſilk. And if the entering ſurface of the glaſs be ſupplied with electricity, it will give it out at the other extremity of contact; that is to ſay, if inſulated conductors be applied at the touching ends of the ſilk, the one will give, and the other receive, electricity, until the intenſities of their oppoſite ſtates are as high as the power of the apparatus can bring them; and theſe ſtates will be inſtantly reverſed by turning the cylinder in the oppoſite direction.

215
How to produce both electricities in the ſame conductor.

As this diſcovery promiſes to be of the greateſt uſe in electrical experiments, becauſe it affords the means of producing either the *plus* or *minus* ſtates in one and the ſame conductor, and of inſtantly repeating experiments with either power, and without any change of poſition or adjuſtment of the apparatus, it evidently deſerved the moſt minute examination.

18. There was little hope (par. 6.) that cuſhions could be diſpenſed with. They were therefore added; and it was then ſeen, that the electrified conductors were ſupplied by the difference between the action of the cuſhion which had the advantage of the ſilk, and that which had not; ſo that the naked face of the cylinder was always in a ſtrong electric ſtate. Methods were uſed for taking off the preſſure of the receiving cuſhion; but the extremity of the ſilk, by the conſtruction, not being immediately under that cuſhion, gave out large flaſhes of electricity with the power that was uſed. Neither did it appear practicable to preſent a row of points or other apparatus to intercept the electricity which flew round the cylinder; becauſe ſuch an addition would have materially diminiſhed the intenſity of the conductor, which in the uſual way was ſuch as to flaſh into the air from rounded extremities of four inches diameter, and made an inch and half ball become luminous and blow like a point. But the greateſt inconvenience was, that the two ſtates with the backward and forward turn were ſeldom equal; becauſe the diſpoſition of the amalgam on the ſilk, produced by applying the leather to the cylinder in one direction of turning, was the reverſe of what muſt take place when the contrary operation was performed.

Notwithſtanding all this, as the intenſity with the two cuſhions was ſuch as moſt operators would have called ſtrong, the method may be of uſe, and I ſtill mean to make more experiments when I get poſſeſſion of a very large machine which is now in hand.

216
Improved method of excitation.

19. The more immediate advantage of this diſcovery is, that it ſuggeſted the idea of two fixed cuſhions with a moveable ſilk flap and rubber. Upon this principle, which is ſo ſimple and obvious, that it is wonderful it ſhould have been ſo long overlooked, I have conſtructed a machine with one conductor, in which the two oppoſite and equal ſtates are produced by the ſimple proceſs of looſening the leather rubber, and letting it paſs round with the cylinder (to which it adheres) until it arrives at the oppoſite ſide, where it is again faſtened. A wiſh to avoid prolixity prevents my deſcribing the mechaniſm by which it is let go and faſtened in an inſtant, at the ſame time that the cuſhion is made either to preſs or is withdrawn, as occaſion requires.

20. Although the foregoing ſeries of experiments naturally lead us to conſider the ſilk as the chief agent in excitation; yet as this buſineſs was originally performed by a cuſhion only, it becomes an object of inquiry to determine what happens in this caſe.

217
In what manner excitation is performed by a ſimple rubber without ſilk flap.

21. The great Beccaria inferred, that in a ſimple cuſhion, the line of fire, which is ſeen at the extremity of contact from which the ſurface of the glaſs recedes, conſiſts of returning electricity; and Dr Nooth grounded his happy invention of the ſilk flap upon the ſame ſuppoſition. The former aſſerts, that the lines of light both at the entering and departing parts of the ſurface are abſolutely ſimilar; and thence infers, that the cuſhion receives on the one ſide, as it certainly does on the other. I find, however, that the fact is directly contrary to this aſſertion; and that the oppoſite inference ought to be made, as far as this indication can be reckoned concluſive: for the entering ſurface exhibits many luminous perpendiculars to the cuſhion, and the departing ſurface exhibits a neat uniform line of light. This circumſtance, together with the conſideration that the line of light behind the ſilk in par. 8. could not conſiſt of returning electricity, ſhowed the neceſſity of farther examination. I therefore applied the edge of the hand as a rubber, and by occaſionally bringing forward the palm, I varied the quantity of electricity which paſſed near the departing ſurface. When this was the greateſt, the ſparks at the electrometer were the moſt numerous. But as the experiment was liable to the objection that the rubbing ſurface was variable, I paſted a piece of leather upon a thin flat piece of wood, then amalgamed its whole ſurface, and cut its extremity off in a neat right line cloſe to the wood. This being applied by the conſtant action of a ſpring againſt the cylinder, produced a weak excitation; and the line where the contact of the cylinder and leather ceaſed (as abrupt-

ly as poſſible) exhibited a very narrow fringe of light. Another piece of wood was prepared of the ſame width as the rubber, but one quarter of an inch thick, with its edges rounded, and its whole ſurface covered with tin-foil. This was laid on the back of the rubber, and was there held by a ſmall ſpring, in ſuch a manner as that it could be ſlided onward, ſo as occaſionally to project beyond the rubber, and cover the departing and excited ſurface of the cylinder without touching it. The ſparks at the electrometer were four times as numerous when this metallic piece was thus projected; but no electricity was obſerved to paſs between it and the cylinder. The metallic piece was then held in the hand to regulate its diſtance from the glaſs: and it was found, that the ſparks at the electrometer increaſed in number as it was brought nearer, until light appeared between the metal and the cylinder; at which time they became fewer the nearer it was brought, and at laſt ceaſed when it was in contact.

218 Concluſions from theſe experiments.

The following concluſions appear to be deducible from theſe experiments. 1. The line of light on a cylinder departing from a ſimple cuſhion conſiſts of returning electricity: 2. The projecting part of the cuſhion compenſates the electricity upon the cylinder, and by diminiſhing its intenſity prevents it ſtriking back in ſuch large quantities as it would otherwiſe do: 3. That if there was no ſuch compenſation, very little of the excited electricity would be carried off: And, 4. That the compenſation is diminiſhed, or the intenſity increaſed, in a higher ratio than that of the diſtance of the compenſating ſubſtance; becauſe, if it were not, the electricity which has been carried off from an indefinitely ſmall diſtance, would never fly back from a greater diſtance and form the edge of light.

219 How to increaſe the intenſity of electricity to a great degree.

22. I hope the conſiderable intenſity I ſhall ſpeak of will be an apology for deſcribing the manner in which I produce it. I wiſh the theory of this very obſcure proceſs were better known; but no conjecture of mine is worth mentioning. The method is as follows:

Clean the cylinder, and wipe the ſilk.

Greaſe the cylinder by turning it againſt a greaſed leather till it is uniformly obſcured. I uſe the tallow of a candle.

Turn the cylinder till the ſilk flap has wiped off ſo much of the greaſe as to render it ſemitranſparent.

Put ſome amalgam on a piece of leather, and ſpread it well, ſo that it may be uniformly bright, Apply this againſt the turning cylinder. The friction will immediately increaſe, and the leather muſt not be removed until it ceaſes to become greater.

Remove the leather, and the action of the machine will be very ſtrong.

My rubber, as before obſerved, conſiſts of the ſilk flap paſted to a leather, and the cuſhion is preſſed againſt the ſilk by a ſlender ſpiral ſpring in the middle of its back. The cuſhion is looſely retained in a groove, and reſts againſt the ſpring only, in ſuch a manner that by a ſort of libration upon it as a fulcrum, it adapts itſelf to all the irregularities of the cylinder, and never fails to touch it in its whole length. There is no adjuſtment to vary the preſſure, becauſe the preſſure cannot be too ſmall when the excitation is properly made. Indeed the actual withdrawing of the cuſhion to the diſtance of $\frac{1}{10}$th of an inch from the ſilk, as in par. 2. will not materially affect a good excitation.

The amalgam is that of Dr Higgins, compoſed of zinc and mercury. If a little mercury be added to melted zinc, it renders it eaſily pulverable, and more mercury may be added to the powder to make a very ſoft amalgam. It is apt to cryſtallize by repoſe, which ſeems in ſome meaſure to be prevented by triturating it with a ſmall proportion of greaſe; and it is always of advantage to triturate it before uſing.

A very ſtrong excitation may be produced by applying the amalgamed leather to a clean cylinder with a clean ſilk: but it ſoon goes off, and is not ſo ſtrong as the foregoing, which laſts ſeveral days.

220 Effects of different cylinders excited in this manner.

23. To give ſome diſtinctive criterions by which other electricians may determine whether the intenſity they produce exceeds or falls ſhort of that which this method affords, I ſhall mention a few facts.

With a cylinder 7 inches' diameter and cuſhion 8 inches long, three bruſhes at a time conſtantly flew out of a 3-inch ball in a ſucceſſion too quick to be counted, and a ball of $1\frac{1}{2}$ inch diameter was rendered luminous, and produced a ſtrong wind like a point. A 9-inch cylinder with an 8-inch cuſhion occaſioned frequent flaſhes from the round end of a conductor 4 inches diameter: with a ball of $2\frac{1}{2}$ inches in diameter the flaſhes ceaſed now and then, and it began to appear luminous: a ball of $1\frac{1}{2}$ inch diameter firſt gave the uſual flaſhes: then, by quicker turning, it became luminous with a bright ſpeck moving about on its ſurface, while a conſtant ſtream of air ruſhed from it: and, laſtly, when the intenſity was greateſt, bruſhes of a different kind from the former appeared. Theſe were leſs luminous, but better defined in the branches; many ſtarted out at once with a hoarſe ſound. They were reddiſh at the ſtem, ſooner divided, and were greeniſh at the point next the ball, which was braſs. A ball of $\frac{4}{10}$ths of an inch in diameter was ſurrounded by a ſteady faint light, enveloping its exterior hemiſphere, and ſometimes a flaſh ſtruck out at top. When the excitation was ſtrongeſt, a few flaſhes ſtruck out ſidewiſe. The horizontal diameter of the light was longeſt, and might meaſure one inch, the ſtem of the ball being vertical.

With a 12-inch cylinder and rubber of $7\frac{1}{2}$ inches, a 5-inch ball gave frequent flaſhes, upwards of 14 inches long, and ſometimes a 6-inch ball would flaſh. I do not mention the long ſpark, becauſe I was not provided with a favourable apparatus for the two larger cylinders. The 7-inch cylinder affords a ſpark of $10\frac{3}{4}$ inches at beſt. The 9-inch cylinder, not having its conductor inſulated on a ſupport ſufficiently high, afforded flaſhes to the table which was 14 inches diſtant. And the 12-inch cylinder, being mounted only as a model or trial for conſtructing a larger apparatus, is defective in ſeveral reſpects, which I have not thought fit to alter. When the five-inch ball gives flaſhes, the cylinder is enveloped on all ſides with fire which ruſhes from the receiving part of the conductor."

221 Uſual methods of eſtimating the comparative power of electrical machines.

It is of conſequence that electricians ſhould employ ſome common method of eſtimating the power of their machines, ſo as to admit of comparing thoſe of different ſizes or conſtructions. This is uſually done by deſcribing the length and appearance of the ſimple ſpark drawn from the prime conductor; or the diſtance to which

Principles of Electricity illuſtrated by experiment.

which the attractive power of the prime conductor is rendered perceptible on a thread or other pendulous body; or laſtly, the exploſion produced from a certain extent of coated ſurface. The firſt of theſe methods is ſubject to conſiderable variation from the circumſtances mentioned in (88), and the ſecond is ſubject to modification both from the ſtructure of the leſs eſſential parts of the machine, and from the dimenſions and figure of the apartment in which the experiments are made. The laſt method is therefore moſt generally employed, and according to this, Mr Nicholſon gives the following eſtimate of the comparative power of Van Marum's two machines deſcribed in n° 48, 49.

222 Comparative power of Van Marum's machines.

By 150 turns of his new machine, 90 jars, each containing upwards of a ſquare foot of coated glaſs, were charged ſo that the battery diſcharged itſelf. The great Teylerian machine, with two plates of ſixty-five inches diameter, in its original ſtate, before Dr Van Marum's improved rubbers were applied to it, never charged the ſame battery, in the moſt favourable circumſtances, in leſs than 66 turns. It follows, therefore, that this ſmall and ſimple machine exhibited $\frac{66}{150}$ths, or about $\frac{4}{9}$ths, of the power of that great machine in its firſt ſtate; and probably, if the circumſtances had been alike favourable in each, it would have amounted to one half. The doctor has grounded a calculation upon theſe facts; but as he ſtates the rubbed ſurfaces of theſe two machines, probably by ſome miſtake in calculation, to be 1243 and 9636 ſquare inches reſpectively, I ſhall repeat the calculation in this place.

The diameter of the plate is 31 inches, and the length of the cuſhion 9 inches. Then $31 .7854 - \overline{31-18}|^2 .7854 = 522$ ſquare inches rubbed by one cuſhion on one ſide. And $522 \times 4 = 2088$ ſquare inches rubbed by the four cuſhions. Again, in the great machine, the two plates having a diameter of 65 inches, and eight cuſhions of $15\frac{1}{2}$ inches long, $\overline{65}|^2 .7854 - \overline{65-31}|^2 .7854 = 2410.4$. And $2410\ 4 \times 8 = 19283$ ſquare inches rubbed. But the intenſity of the electric power of a machine will be in the compound ratio inverſely of the ſurfaces and number of turns when the charge is the ſame; Or $150 \times 2088 : 66 \times 19283 :: 1 =$ the intenſity of the larger machine : $4 =$ the intenſity of the ſmaller.

To have increaſed the power of ſteady excitation four-fold, is certainly an aſtoniſhing acquiſition. This expreſſion, however, of the intenſities appears to be leſs generally uſeful than that of the ratio of the ſurface rubbed, to that which is charged. This laſt expreſſion becomes very ſimple when the latter quantity is reduced to 1, or unity. Thus, in the two machines here mentioned, the rubbed ſurfaces in inches for the battery are $\frac{19283 \times 66}{90 \times 144}$, and $\frac{2088 \times 150}{90 \times 144}$, which are equal to the ſimple numbers 90.5 and 24.0, which reſpectively denote the number of inches rubbed to charge one inch of coated glaſs.

223 Plate machine preferable to a cylindrical.

From comparing the effects of his own machines in the higheſt degree of excitation with thoſe produced by the great machine at Haarlem, Mr Nicholſon had been induced to give the preference to the cylinder. From later experience, however, and the account of the effects produced by Van Marum's new machine, Mr Nicholſon has been led to alter his opinion; and he now prefers a plate to a cylinder.

Principles of Electricity illuſtrated by experiment.

224 Cuthbertſon's method of meaſuring the power of machines.

From conſidering the defects of the uſual methods of eſtimating the power of machines, Mr Cuthbertſon was led to propoſe the exploſion of ſteel wire as a proper meaſure; and he has made ſeveral experiments to ſhew that this method is the leaſt liable to error. Mr Nicholſon has given an account of theſe experiments in his Journal for Auguſt 1798; but they ſeem to require a repetition and farther extenſion before they can be received as concluſive.

225 Subſtitutes for glaſs in electrical machines.

As glaſs, though preferable to all electrics that can be employed for the purpoſes of excitation, from its durability and unchangeable nature, is from its brittleneſs attended with conſiderable expence, various expedients have been thought of to ſubſtitute in its place ſome other electric in the conſtruction of electrical machines.

Dr Ingenhouſz, the inventor of the plate machine, made a variety of experiments for this purpoſe. Paſteboard thoroughly dried and heated, and then ſoaked and varniſhed with a ſolution of amber in linſeed oil, formed plates which were ſtrongly electrified when rubbed with a cat's ſkin or hare's ſkin. He tried baked wood boiled in linſeed oil, but with leſs ſucceſs. A cylinder of ſtrong ſilk velvet, formed by ſtretching that ſubſtance upon two circular wooden diſks, was found to afford conſiderable electrical force when cauſed to revolve againſt a cuſhion covered with hare's ſkin*. And laſtly, the ſame philoſopher contrived a portable apparatus for charging a jar by means of a varniſhed ſilk ribband, expoſed to the friction of a rubber attached to the external coating, while the oppoſite electricity of the ſilk was taken off by a metallic part communicating with the inſide.

It was at the beginning of 1784, that M. Walckiers de St Amand undertook to conſtruct a machine, in which a piece of ſilk was made to revolve inceſſantly, and paſs between two pair of rubbers. He made one of ſmall dimenſions, and afterwards a larger one, in which the ſilk was twenty-five feet in length, and five feet broad. In the following year M. Rouland, profeſſor of natural philoſophy in the univerſity of Paris, conſtructed a machine of the ſame kind †. As the advantages and effects of theſe machines appear to be conſiderable, we ſhall here inſert the deſcription of the latter from Nicholſon's Journal for December 1798.

226 Deſcription of a ſilk machine. Plate CLXXXIX. N° 2.

A, B, fig. 80. is a wooden table four feet and a half long, two feet nine inches wide, and ſomewhat more than an inch and a half thick: its feet are 18 inches long. Upon this table are faſtened by ſtrong wooden ſcrews, *a b c d*, two croſs pieces, each nine inches broad, which carry the uprights C, D, E, F, which laſt are 27 inches in height. At about two-thirds or more of the height of theſe uprights, there are cut notches of an inch ſquare each, in which the axes of the two cylinders G and H turn freely. Theſe axes are parallel to the table and to each other, and are kept in their place by clamps of wood ſcrewed over them. The cylinders G and H are formed of light wood glued together, and covered at the ends by a circular piece, whoſe rounded edges ariſe half an inch above the ſurface of the cylinders themſelves. Their diameter is eight inches; the axes are of box-wood, and are leſs than an inch in diameter, having a ſhoulder which prevents the ends of the cylinders

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* *Phil. Tranſ.* for 1779.

† *Deſcription des machines electrique à taffetas par M. Rouland.*

from touching the uprights when turned round; and laſtly, the cylinders are covered with ſerge.

The handle is copper, its radius being ſix inches long.

K, L, is a piece of taffety covered with oily and reſinous matter, of the ſame kind as is uſed in France in the conſtruction of air-balloons, which, M. Rouland ſays, renders the ſilk very electrical: the breadth of the ſilk is nearly one inch leſs than the length of the cylinders, and it is wrapped round them with its ends ſewed together.

The whole breadth of the ſilk is taken hold of or pinched between two flattened tin tubes oppoſite each other at M, and two of the ſame kind at N: theſe are the rubbers, and may be made to preſs againſt each other, more or leſs ſtrongly, by means of ſcrews. They are retained by ſtrings of ſilk faſtened to the four uprights of the machine. *v v* are two braſs chains hooked upon the rubbers, and communicating with the earth; *o p* and *q r* are four pieces of taffety, prepared in the ſame manner as the principal piece, ſewed in the direction of their length to the rubbers, and faſtened to each other by their correſponding corners by means of threads of ſilk. The metallic tubes or rubbers are covered with cat's ſkin.

S repreſents the conductor. It is a cylinder of braſs three inches in diameter, 36 inches in length, including the balls at the end, whoſe diameters are four inches: one of theſe balls has a ring, *t*, above it, which ſerves to form a communication between the conductor S and any other conductor.

The upper and lower parts of this cylindrical prime conductor are armed with two plates of braſs *y y*, whoſe length is equal and correſpondent to the breadth of the taffety, which is 26 inches, and 132 inches or 11 feet long: the edges of the plates are about half an inch diſtant from the ſilk, and ſerve inſtead of the metallic points that were uſed by M. Walckiers, but rejected by M. Rouland, becauſe they were apt to ſtick into the ſilk and damage it.

The conductor S is ſuſpended by ſilk ſtrings, faſtened to the uprights of the machine by the hooks and rings *i i*: its ſituation is parallel to the cylinders G, H, and equidiſtant from each. The action of this machine is as follows: The cylinder H is moved rapidly on its axis by means of the handle, and the cylinder G moves of courſe in the ſame direction on the two extremities of its axis, provided the taffety K, L, be properly ſtretched. This tenſion is eaſily obtained; becauſe the croſs pieces to which the uprights C, D, and E, F, are fixed, may be moved nearer or further from each other, and faſtened by means of the ſcrews *a b* and *c d*, which paſs through holes cut in the direction of the table.

The rotation of the cylinders neceſſarily producing a circulation of the taffety, it muſt conſequently be rubbed in its paſſage between the tin tubes covered with cat's ſkin at M and N; and by this friction it obtains what is called the negative electricity, which is communicated from both parts of the ſilk to the common conductor S. But it may be made to electrify poſitively, by removing the rubbers to the middle of the ſilk, ſo that the prime conductor may communicate with them: or, if the two cuſhions be removed to half the diſtance between the revolving cylinders and the prime conductor, poſitive and negative electricity may be had at the ſame time, the rubbers being in a negative ſtate, and the prime conductor in a poſitive ſtate.

The advantages of a machine of this conſtruction beyond thoſe of glaſs are ſtated by the inventor to be, 1. It is not brittle in any part. 2. Its excitation is more ſteady, becauſe it requires no amalgam. 3. Its dimenſions have no limit.

The power of excitation in this way appears to have been very conſiderable. The facts are not related with ſo much detail as could be wiſhed in the report of the academy; but it appears that the negative ſparks from the conductor of Walckiers, which was five feet long, were from 15 to 17 inches in length, very loud and denſe, and very painful to the hand; that pointed bodies emitted very ſenſible ſparks to the conductor; and that a battery of 50 ſquare feet was charged by 30 turns of the machine, which gives 19 feet of ſilk rubbed to charge one foot of glaſs*. In another inſtance, however, it is ſaid, that a ſquare foot was charged by one turn of the machine, which anſwered to 31½ ſquare feet of ſilk. It is not ſaid whether the labour of turning was conſiderable or not.

M. Rouland made ſeveral trials to ſubſtitute plain ſilk inſtead of that which was varniſhed; and he alſo tried woollens and mixed cloth containing goat's hair; but none of theſe anſwered to his ſatisfaction.

CHAP. XII. *Of the Electric Properties of Air.*

227 Heated air ſaid to be a conductor.

WE have ranked air among the electrics, but it will be ſeen by the table of electric ſubſtances given in page 646. that it is but an imperfect electric. We have obſerved at the beginning of this part, that it may even become a conductor by being impregnated with moiſture. It is alſo found that when air is heated to a conſiderable degree, it becomes a conductor; this according to Cavallo, may be ſhewn by the following experiment. Electrify a common ball electrometer, or the prime conductor with Henly's quadrant electrometer placed upon it; the balls will, of courſe, ſeparate from each other, or the index of the quadrant will denote the degree of electricity communicated to the prime conductor. Now bring a red-hot iron within a ſufficient diſtance of the electrometer or the prime conductor, and it will be found that they ſoon loſe their electricity, it being conducted away by the heated air that ſurrounds the iron; that the heated iron is the cauſe of the loſs of electricity may be proved, by repeating the experiment with the ſame iron when cold, as in this caſe it will be found that the electrometer of the conductor, will not loſe its electricity ſo ſoon, unleſs the iron be brought very near.

Mr Read made the following experiment to prove that hot air is not a conductor.

228 This denied by Mr Read.

"It has been," ſays Mr Read, "commonly ſaid, that hot air conducts electricity. With a view to aſcertain this matter, the following experiments were made. To one end of a long piece of wood (which ſerved as a handle,) was fixed a glaſs rod fifteen inches long; to the remote end of the glaſs was fixed a pith-ball electrometer. Having electrified the balls, I held them by the wood handle, and projected them into a large oven, immediately after the fire was drawn out of it; the conſequence was, that when I performed the operation ſlowly, the balls loſt their electricity; but that

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* See *Phil. Journal*, i. 87.

that when done quick, with as little delay as poſſible, their electric charge was not diminiſhed. The loſs of electricity, in the firſt caſe, was found to have eſcaped along the glaſs into the wooden handle, and ſo to the earth, owing to the great heat the glaſs rod had acquired, by which it became a conductor of the fluid; for until it had cooled a little, the balls could not be charged again.

"I ſhall lay before the reader one circumſtance more, becauſe it may tend to throw light on what degree of heat the oven was in at the time the obſervations were made. The baker having pointed out to me the hotteſt part of the oven; with a quick motion in and out, I plunged the electrified balls into that part of it, by which one thread ball was burned off, but the remaining ball ſhewed that it ſtill retained its electric charge, becauſe it was ſtrongly attracted on the approach of my finger *.

Air, as an electric, may be electrified either by *excitation* or by *communication*.

229 Means of exciting air.

Air may be excited by any circumſtance which tends to produce motion among its particles; as by friction, evaporation, heat and cold, expanſion and contraction, and by any chemical proceſſes in which theſe circumſtances are produced.

230 Friction.

1. That air may be excited by friction was ſufficiently ſhown by the experiments related to demonſtrate the ſenſibility of Bennet's electrometer; by theſe experiments it appeared, that whenever a cloud of duſt or powder was raiſed in the air ſurrounding the electrometer, the ſlips of gold leaf, by their ſeparation, manifeſted ſigns of electricity, which muſt doubtleſs have been produced by the attraction of the particles of duſt or powder againſt the particles of air.

231 Evaporation.

2. Air may be rendered electrical by the vapour or ſmoke which riſes into it from evaporating or burning ſubſtances. At the end of the firſt part of this article, we noticed, in a general way, Sig. Volta's experiments on the electricity produced by evaporation; we muſt now conſider this ſubject rather more at large. The production of electricity by evaporation, may be ſhown by the following experiments.

Plate CXCI.

Exper. 1. Upon the cap of Bennet's electrometer *c*, fig. 81. place a metallic cup containing a little water; drop into the water a red-hot coal, or a red-hot piece of clean iron; a vapour will ariſe from the water, and the ſtrips of gold leaf *n n* will diverge with ſtrong negative electricity. If at the ſame time, an iron wire *p*, fixed to a rod of glaſs or ſealing-wax, with a common ball electrometer hanging from its extremity, be held by the glaſs or ſealing-wax in the air, at a little diſtance above the cup, the balls *d* will be found to diverge with poſitive electricity.

Exper. 2. Let there be two of the above electrometers, as A, B, fig. 82.; upon the cap of the electrometer B, place a metallic cup *d*, as in the laſt experiment, and into the cap of the electrometer A, let there be ſcrewed a bent wire *m*, with a piece of tin *s* ſoldered to its other extremity. If now, the electrometer B with its metallic cup be placed immediately below the tin *s*, and a cullender *c*, containing a few live coals, be held over the cup, and if water be poured from the jug upon the coals in the cullender, ſo as to fall into the metal cup, the ſlips of gold leaf in both electrometers will diverge; thoſe of the electrometer B, with negative electricity, and thoſe of the electrometer A, with poſitive electricity.

The experiments on the electricity produced by evaporation, may be very conveniently made by heating the ſmall end of a pretty long tobacco-pipe, and pouring water into the bowl of it; the water running down to the heated part, which ſhould be held over the cap of Bennet's electrometer, is ſuddenly expanded into vapour, and the ſlips of gold leaf will ſeparate with negative electricity.

232 The electricity of evaporating bodies not always negative.

In the above experiment it has been ſeen, that the electrometer from which the vapour aroſe, was always electrified negatively; from having obſerved this to be always the caſe in his experiments, Sig. M. Volta conſidered it as a general law. Mr Cavallo, however, mentions ſome experiments made by a profeſſor at Mantua, and by himſelf, which ſeem to contradict this ſuppoſition.

All the experiments, (ſays Mr Cavallo), made on evaporation for ſome years after this diſcovery, were attended with reſults conformable to the above-mentioned general law; but two remarkable exceptions have of late been diſcovered, which, beſides their contradicting the ſaid law, ſeem to point out a more intimate connection between the electric fluid and other bodies. The firſt of thoſe exceptions was diſcovered and publiſhed three years ago, by a learned profeſſor of the academy of Mantua; the ſecond was very lately diſcovered by myſelf.

The Mantuan profeſſor obſerved, that when water was evaporated by being put in contact with a red hot piece of ruſty iron, it would leave the iron electrified poſitively; whereas when the experiment was tried with a clean piece of iron, the electricity acquired by the metal would be of the negative kind.

When I firſt attempted to repeat this curious experiment, the reſult did by no means anſwer my expectations; the electricity, which was produced being of the negative, and not of the poſitive kind; but obſerving that ſometimes no ſenſible degree of electricity was produced, though the evaporation was very quick and copious, I began to ſuſpect that the iron, which I had employed, was not ſufficiently covered with ruſt, in conſequence of which two oppoſite ſtates of electricity might poſſibly be produced, viz. the negative from the clean, and the poſitive from the ruſty part of the iron: which two oppoſite ſtates, by counteracting each other, would leave the iron un-electrified. Afrer various repetitions of this experiment, in which the red-hot iron was thrown into the inſulated water, or the water was poured upon the red-hot and inſulated iron, I found that this was actually the caſe.

I procured ſome old iron nails, which had remained expoſed to the atmoſphere for ſeveral years, and of courſe had contracted a very thick coat of ruſt; and on performing the experiment with them, I obtained poſitive electricity, agreeably to the aſſertion of the above-mentioned gentleman. The ſame nail very ſeldom would anſwer for more than one experiment; for the action of the fire and of the water generally removed a great deal of the ruſt, and exhibited the naked metal, which would afterwards acquire the negative electricity. Here follows the manner of performing this remarkable experiment.

Inſulate a metallic or earthen plate, and pour a

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* *Read's ſummary view of ſpontaneous electricity.*

ſmall quantity of water in it, and let a ſenſible electrometer be connected with the water; then drop a red-hot piece of iron into the plate, and it will be found, that, if very ruſty iron be uſed, the electrometer will be opened with poſitive electricity; if the iron be clean, or free from ruſt, the electrometer will acquire the negative electricity; and laſtly, if the iron be partially ruſty, the electrometer will acquire little or no electricity, though in every caſe the evaporation may be equally quick and copious.

The other exception of the above-mentioned general law is ſhown by means of red-hot glaſs, which I chanced to diſcover very lately. The various degrees of electric power that are produced by the evaporation of water from different ſubſtances induced me to diverſify the experiments as much as I could, in order to diſcover, if poſſible, the reaſon why thoſe different effects took place when the evaporation ſeemed to be equally quick and copious. Amongſt other ſubſtances, I tried glaſs, and found that it generally produced little or no electricity. The water was ſometimes poured upon the hot glaſs, but in general the hot glaſs was dropped into the inſulated water, which was contained in a tin cup. However, the difference of effect was found not to be occaſioned by thoſe two different modes of proceeding. Having repeated this experiment a great many times, I at laſt found, that the effect depended on the different nature of the glaſs. If white and clean flint glaſs be made red-hot, and in that ſtate be dropped into the veſſel of water, a quick evaporation will enſue, and the veſſel is electrified poſitively. If the flint glaſs be not very clear, there will not be any electricity generated by the evaporation, &c. And laſtly, if the experiment be tried with more impure glaſs, as the glaſs of which wine bottles are made, the negative electricity will be produced.

In performing this experiment, it is neceſſary to take care that no pieces of coal adhere to the glaſs, which will frequently happen when a piece of glaſs is heated in a common fire; for in that caſe negative electricity will be produced by the evaporation, though the beſt flint glaſs be uſed.

It has frequently happened, in the courſe of my experiments, that no electricity whatever has been produced by the evaporation of water from certain ſubſtances; however, as in thoſe caſes the evaporation was not very copious, I attributed the deficiency of electricity to the weakneſs of the evaporation. But a very remarkable inſtance of this ſort is mentioned in the diſſertation of the above-mentioned ingenious profeſſor. He ſlaked 25 pounds weight of quicklime with a ſufficient quantity of water, and though a very copious evaporation took place, yet it was not attended with any electricity. Should any perſon ſuſpect, that the deficiency of electricity in this experiment was owing to the want of burning coals or actual fire, he ſhould conſider, that in other ſimilar proceſſes electricity is produced without any actual fire; thus the evaporation, which is occaſioned by the efferveſcence of iron filings in diluted vitriolic acid, produces negative electricity.

After a careful examination of the above-mentioned experiments, the origin of the electricity, which is obſerved in the evaporation of water and other evaporable ſubſtances, whether ſolid or fluid, ſeems not to be reconcileable to the general law already noticed, nor can I form any plauſible theory that can be ſufficient to account for all the phenomena. If the production of electricity in thoſe experiments depended upon the increaſed or diminiſhed capacity of water for holding the electric fluid, it ſhould ſeem to be immaterial whether the water be evaporated in one way or in another, provided the evaporation be made with equal quickneſs and in equal quantities. Were it not known that glaſs or iron made red-hot produces no electricity in cooling, we might ſuſpect, that the electricity, which is produced by the evaporation of water, may be counteracted by the contrary electricity, which is produced by the cooling of glaſs or iron; but it has been obſerved by ſeveral ingenious perſons, that red-hot glaſs and red-hot iron produce no electricity whatever when ſuffered to cool upon inſulated ſtands.

It has been found that electricity promotes evaporation. This may be proved by the following

233 Evaporation increaſed by electricity

Exper. Upon the prime conductor of an electrical machine, place a ſhallow metallic diſh, as a pewter plate, containing a ſmall quantity of water; and let a ſimilar diſh, containing ſuch a quantity of water as that the two diſhes may exactly counterpoiſe each other, be placed on a table at a diſtance from the machine. Now ſet the machine in motion, and after a certain time has elapſed, place the two diſhes again in the ſcales, and it will be found that the diſh which ſtood on the prime conductor is lighter than the other; evidently ſhowing that more of the water has been evaporated.

This experiment might with more propriety have been given when deſcribing the chemical effects of the electric power.

We ſhall return to this ſubject, under *Atmoſpherical Electricity*, to which the conſideration of the other circumſtances effecting the electricity of air by *excitation*, more properly belongs.

234 Method of electrifying the air of a room.

Air may be electrified by communication in two ways; by *ſimple electrification*, as it is called, or by charging a ſtratum of it ſituated between two conducting ſurfaces.

Exper. 1.—Fix two or three pointed needles into the prime conductor of an electrical machine, and ſet the glaſs in motion ſo as to keep the prime conductor electrified for ſeveral minutes. If now, an electrometer be brought within the air that is contiguous to the prime conductor, it will exhibit ſigns of electricity, and this air will continue electrified for ſome time, even after the machine has been removed into another room. The air, in this caſe, is electrified poſitively; it may be negatively electrified by fixing the needles in the negative conductor while inſulated, and making a communication between the prime conductor and the table, by means of a chain or other conducting ſubſtance.

The air of a room may be electrified in another way. Charge a large jar, and inſulate it; then connect two or more ſharp pointed wires or needles, with the knob of the jar, and connect the outſide coating of the jar with the table. If the jar be charged poſitively, the air of the room will ſoon become poſitively electrified likewiſe; but if the jar be charged negatively, the electricity communicated by it to the air, will become alſo negative. A charged jar being held in one hand, and the flame of an inſulated candle, held in the other, being brought near the knob of the jar, will alſo produce the ſame effect.

A ſtratum of air may be charged in the ſame manner as a plate of glaſs, when its oppoſite ſurfaces are placed in contact with metallic plates which ſerve as a coating to the plate of air.

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Method of charging a plate of air.

To perform this experiment, take two circular boards, each three or four feet in diameter, made perfectly ſmooth, and their edges rounded; coat one ſide of each board with tinfoil, ſo that it may be turned up over the edge of the board, and let it be burniſhed ſo as to render it as ſmooth as poſſible. Theſe boards muſt be placed, with their coated ſides parallel to each other, horizontally, and ſo that they may be ſet at a greater or ſmaller diſtance, and they muſt both be inſulated. For this purpoſe, it is moſt convenient to fix one of the boards on a ſtrong ſupport of glaſs or baked wood, and to ſuſpend the other by ſilken ſtrings from the ceiling of the room, from which it may be raiſed or lowered by a proper pulley, ſo as to be placed at the required diſtance from the lower board.

The boards being thus placed in their ſituation, at the diſtance of about an inch from each other, on their being electrified, the ſtratum of air, interpoſed between them, will preſent phenomena ſimilar to thoſe of a plate of glaſs under the ſame circumſtances. On connecting one of the boards with the prime conductor, while the other is inſulated, the air will receive no charge agreeably to what was remarked of an inſulated Leyden phial. But if, while one of the boards is electrified from the prime conductor, the other be made to communicate with the earth or other conducting bodies, the plate of air will receive a charge, and when the communication between the boards is completed by conductors, an exploſion will take place. The exploſion in this caſe, however, is by no means ſo remarkable as that which is produced from an equal ſurface of coated glaſs, for reaſons which will be explained hereafter.

The experiment of charging a plate of air was firſt made by M. Æpinus and M. Wilcke, who being at Berlin together, jointly made ſeveral experiments.

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This experiment firſt made by Æpinus and Wilcke.

They made ſeveral experiments to give the electric ſhock by means of air, and at length ſucceeded by ſuſpending large boards of wood covered with tin with the flat ſides parallel to one another, and at ſome inches aſunder; for they found, that upon electrifying one of the boards poſitively, the other was always negative. But the diſcovery was made complete and indiſputable by a perſon touching one of the plates with one hand, and bringing his other hand to the other plate; for he then received a ſhock through his body, exactly like that of the Leyden experiment.

With this plate of air, they made a variety of curious experiments. The two metal plates, being in oppoſite ſtates, ſtrongly attracted each other, and would have ruſhed together, if they had not been kept aſunder by ſtrings. Sometimes the electricity of both would be diſcharged by a ſtrong ſpark between them, as when a pane of glaſs burſts with too great a charge. A finger put between them promoted the diſcharge, and felt the ſhock. If an eminence was made on either of the plates, the ſelf diſcharge would always be made through it, and a pointed body fixed upon either of them prevented their being charged at all *.

At the end of the table of conductors given in page 646. it was obſerved that a Torricellian vacuum was a non-conductor of electricity. Some experiments were made by Mr Walſh, which proved the perfect impermeability of a vacuum by the electric light. But the moſt complete experiments on this ſubject are thoſe of Mr W. Morgan and Mr Cavallo. The following are Mr Morgan's experiments.

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Mr Morgan's experiments on the non-conducting power of a perfect vacuum.

A mercurial gage B, fig. 83. about 15 inches long, carefully and accurately boiled, till every particle of air was expelled from the inſide, was coated with tin-foil, five inches down from its ſealed end (A), and being inverted into mercury through a perforation D, in the braſs cap E, which covered the mouth of the ciſtern H; the whole was cemented together, and the air was exhauſted from the inſide of the ciſtern through a valve C, in the braſs cap E juſt mentioned; which producing a perfect vacuum in the gage B, afforded an inſtrument peculiarly well adapted for experiments of this kind. Things being thus adjuſted, a ſmall wire, F, having been previouſly fixed on the inſide of the ciſtern, to form a communication between the braſs cap E, and the mercury G, into which the gage was inverted; the coated end A was applied to the conductor of an electrical machine; and, notwithſtanding every effort, neither the ſmalleſt ray of light, nor the ſlighteſt charge, could ever be procured in this exhauſted gage. It is well known, that if a glaſs tube be exhauſted by an air-pump, and coated on the outſide, both light and a charge may very readily be procured. If the mercury in the gage be imperfectly boiled, the experiment will not ſucceed; but the colour of the electric light, which, in air rarefied by an exhauſter, is always violet or purple, appears in this caſe of a beautiful green; and what is very curious, the degree of the air's rarefaction may be nearly determined by this means. There have been inſtances known, in a courſe of experiments, where a ſmall particle of air having found its way into the tube B, the electric light became viſible, and as uſual of a green colour; but the charge being often repeated, the gage has at length cracked at its ſealed end, and in conſequence the external air, by being admitted into the inſide, has gradually produced a change in the electric light, from green to blue, from blue to indigo, and ſo on to violet and purple, till the medium has at laſt become ſo denſe, as no longer to be a conductor of electricity. There can be little doubt, from the above experiments, of the non-conducting power of a perfect vacuum; and this fact is ſtill more ſtrongly confirmed by the phenomena which appear upon the admiſſion of a very minute particle of air into the inſide of the gage. In this caſe, the whole becomes immediately luminous, upon the ſlighteſt application of electricity, and a charge takes place, which continues to grow more and more powerful, in proportion as freſh air is admitted, till the denſity of the conducting medium arrives at its maximum, which it always does when the colour of the electric light is indigo or violet. Under theſe circumſtances, the charge may be ſo far increaſed, as frequently to break the glaſs. In ſome tubes, which have not been completely boiled, they will not conduct the electric fluid, when the mercury is fallen very low in them; yet upon letting in air into the ciſtern H, ſo that the mercury ſhall riſe in the gage B, the electricity, which was before latent in the inſide, ſhall now become viſible, and as the mercury continues to riſe, and of conſequence the medium is rendered leſs rare, the light ſhall grow

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* *Æpini Tentamen.*

grow more and more viſible, and the gage ſhall at laſt be charged, notwithſtanding it has not been near an electrical machine for two or three days. This ſeems to prove, that there is a limit, even in the rarefaction of air, which ſets bounds to its conducting power; or, in other words, that the particles of air may be ſo far ſeparated from each other, as no longer to be able to tranſmit the electricity; that if they are brought within a certain diſtance of each other, their conducting power begins, and continually increaſes, till their approach alſo arrives at its limit, when the particles again become ſo near, as to reſiſt the paſſage of the electricity entirely, without employing violence, which is the caſe in common and condenſed air, but more particularly in the latter.

238 Surpriſing eaſe with which an exhauſted tube may be charged with electricity.

It is ſurpriſing to obſerve, how readily an exhauſted tube is charged with electricity. By placing it at ten or twelve inches from the conductor, the light may be ſeen pervading its inſide, and as ſtrong a charge may ſometimes be procured, as if it were in contact with the conductor. Nor does it ſignify how narrow the bore of the glaſs may be; for even a thermometer tube, having the minuteſt perforation poſſible, will charge with the utmoſt facility; and in this experiment, the phenomena are peculiarly beautiful.

Let one end of a thermometer tube be ſealed hermetically; let the other end be cemented into a braſs cap with a valve, or into a braſs cock, ſo that it may be fitted to the plate of an air-pump. When it is exhauſted, let the ſealed end be applied to the conductor of an electrical machine, while the other end is either held in the hand, or connected to the floor. Upon the ſlighteſt excitation, the electricity will accumulate at the ſealed end, and be diſcharged through the inſide in the form of a ſpark; and this accumulation and diſcharge may be inceſſantly repeated, till the tube is broken. By this means, a ſpark 42 inches long may be procured; and if a proper tube could be found, we might have a ſpark three or four times that length: if, inſtead of the ſealed end, a bulb be blown at that extremity of the tube, the electric light will fill the whole of that bulb, and then paſs through the tube in the form of a brilliant ſpark, as in the foregoing experiment; though in this caſe, the charge, after a few trials, will make a ſmall perforation in the bulb. If, again, a thermometer, filled with mercury, be inverted into a ciſtern, and the air exhauſted in the manner before deſcribed for making the experiment with the gage, a Torricellian vacuum will be produced; and now the electric light in the bulb, as well as the ſpark in the tube, will be of a vivid green; but the bulb will not bear a frequent repetition of charges, before it is perforated in like manner as when it has been exhauſted by an air-pump. It can hardly be neceſſary to obſerve, that in theſe caſes the electricity aſſumes the appearance of a ſpark, (F) from the narrowneſs of the paſſage through which it forces its way. If a tube, 40 inches long, be fixed into a globe eight or nine inches in diameter, and the whole be exhauſted, the electricity, after paſſing in the form of a brilliant ſpark throughout the length of the tube, will, when it gets into the inſide of the globe, expand itſelf in all directions, entirely filling it with a violet and purple light, and exhibiting a ſtriking inſtance of the vaſt elaſticity of the electric power.

Mr Morgan concludes his remarks with acknowledging his obligations to Mr Brooke of Norwich for communicating to him his method of making mercurial gages.

239 Mr Brooke's method of making mercurial gages.

Mr Brooke's method of making mercurial gages is nearly as follows: Let a glaſs tube *L* (fig. 84.), ſealed hermetically at one end, be bent into a right angle within two or three inches of the other end. At the diſtance of about an inch or leſs from the angle, let a bulb *K*, of about three-fourths of an inch in diameter, be blown in the curved end, and let the remainder of this part of the tube be drawn out *I*, ſo as to be ſufficiently long to take hold of when the mercury is boiling. The bulb *K* is deſigned as a receptacle for the mercury, to prevent its boiling over; and the bent figure of the tube is adapted for its inverſion into the ciſtern: for by breaking off the tube at *M* within an eighth or a fourth part of an inch of the angle, the open end of the gage may be held perpendicular to the horizon when it is dipped into the mercury in the ciſtern, without obliging us to bring our finger or any other ſubſtance into contact with the mercury in the gage, which never fails to render the inſtrument imperfect. It is neceſſary to obſerve, that if the tube be 14 or 15 inches long, it will be impoſſible to boil it effectually for the experiments mentioned above in leſs than three or four hours, although Mr Brooke ſeems to preſcribe a much ſhorter time for the purpoſe; nor will it even then ſucceed, unleſs the greateſt attention be paid that no bubbles of air lurk behind, which is frequently the caſe: but experience has taught how to guard pretty well againſt this diſappointment, particularly by taking care that the tube be completely dry before the mercury is put into it; for if this caution be not obſerved, the inſtrument can never be made perfect. There is, however, one evil which it is ſufficient to remedy; and that is, the introduction of air into the gage, owing to the unboiled mercury in the ciſtern: for when the gage has been a few times exhauſted, the mercury which originally filled it becomes mixed with that into which it is inverted, and in conſequence the vacuum is rendered leſs and leſs perfect, till at laſt the inſtrument is entirely ſpoiled.

Mr Cavallo's experiments were made with an excellent air-pump, which is deſcribed in the 73d volume of the Philoſophical Tranſactions.

240 Mr Cavallo's experiments on the ſame ſubject.

The following is the reſult of Mr Cavallo's experiments as given by himſelf.

“ From theſe experiments it appears, firſt, that in the utmoſt rarefaction that can be effected by the beſt air-pump, which amounts to about one thouſand, both the electric light and the electric attraction, though very weak, are ſtill obſervable; but, ſecondly, that the attraction and repulſion of electricity become weaker in proportion as the air is more rarefied, and in the ſame manner the intenſity of the light is gradually diminiſhed. Now, by reaſoning on this analogy, we may conclude

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(F) By cementing the ſtring of a guitar into one end of a thermometer tube, a ſpark may be obtained, as well as if the tube had been ſealed hermetically.

conclude, that both the attraction and the light will ceaſe in a perfect abſence of air; but this will never account for this perfect vacuum ever becoming a nonconductor of electricity; however, the fact ſeems to be fully aſcertained by Mr Walſh and Mr Morgan, and the only thing that remains to be done is to inveſtigate the cauſe of ſo remarkable a property."

Experiments on the action of electrics *in vacuo* had been long ago made by Mr Boyle and Mr Gray; but as the vacuum that they were able to produce was very imperfect, it is not ſurpriſing that they could perceive no difference whether the body was expoſed in the open air or confined within an exhauſted receiver.

CHAP. XIII. *Of the means of aſcertaining ſmall degrees of Electricity.*

241 Uſual electrometers not ſufficiently delicate for nice obſervations.

IN the courſe of this part of our article we have already deſcribed many inſtruments for aſcertaining the preſence of electricity; and one of theſe, *Bennet's Electrometer*, has been ſhewn to be exceedingly ſenſible. But on a nicer examination it has been found, that in the courſe of experiments, as well as in obſervations on natural electricity to be related hereafter, the quantity or degree of electricity is ſo minute, as not to be ſenſible by means even of this delicate inſtrument, and is yet capable of being rendered ſufficiently obvious by other means. Theſe means we are now to deſcribe.

Moſt of the means which have been deviſed for rendering ſenſible minute degrees of electricity have been ſuggeſted by the effects of Volta's electrophorus.

242 Method of Lichtenberg and Klincock.

The firſt proceſs employed for this purpoſe was invented by Profeſſor Lichtenberg, and the ſame thought ſeems to have occurred to Dr Klincock of Prague. It was performed by means of two reſinous plates like thoſe of the common electrophorus, and one metallic plate with an inſulating handle. One of the reſinous plates was firſt excited by ſlight friction, and it was then employed to communicate electricity to the metallic plate, which was in its turn made to communicate electricity to the other reſinous plate. The electricity poſſeſſed by this latter plate was now communicated to the metallic plate: this was again conveyed to the firſt reſinous plate, of which it increaſed the electricity by communication. By repeatedly applying the metallic plate to each of the reſinous plates, without bringing them in contact, the electricity at firſt excited was accumulated till it became ſufficiently ſenſible to an ordinary electrometer *.

243 Experiments which led to the invention of Volta's condenſer. Capacity of conductors.

The next method employed was that of the celebrated Volta, or the condenſer. But before we deſcribe the apparatus and the mode of uſing it, it is neceſſary that we ſhould give a brief account of the experiments which led to the invention.

Mr Volta found that conductors of the ſame ſhape were capable of containing more or leſs electricity, as their ſurfaces are *leſs* or *more* influenced by *homologous atmoſpheres;* and that the *capacity* of a conductor of the ſame ſhape and ſurface was increaſed, when, inſtead of being quite *inſulated*, they were, while inſulated, preſented to another conductor not inſulated, and this increaſe became more conſpicuous according as the two conductors were larger, or approached nearer to each other.

When an inſulated conductor is thus preſented to any other conductor, Signior Volta calls it a *Conjugate Conductor*.

244 Conjugate conductors.

In order to ſhew by experiment the above-mentioned property or increaſe of capacity in a conductor, take the metal plate of an electrophorus, and holding it by its inſulating handle in the air, electrify it ſo high, as that the index of an electrometer annexed to it might be elevated to 60°; then lowering this metal plate by degrees towards a table or other conducting plain ſurface, you will obſerve that the index of the electrometer will fall gradually from 60° to 50°, 40°, 30°, &c. Notwithſtanding this appearance, the quantity of electricity in the plate remains the ſame, except the ſaid plate be brought ſo near the table as to occaſion a tranſmiſſion of the electricity from the former to the latter; at leaſt the quantity of electricity will remain as much the ſame as the dampneſs of the air, &c. will permit. The decreaſe, therefore, of intenſity is owing to the increaſed capacity of the plate, which is now conjugate, viz. oppoſed to another conducting ſurface. In proof of which, remove gradually the metal plate from the table, and it will be found that the electrometer riſes again to its former ſtation, namely to 60°, excepting the loſs of that quantity of electricity, which during the experiment muſt have been imparted to the air.

The two following experiments will throw more light upon the reciprocal action of the electric atmoſpheres. Firſt, ſuppoſe two flat conductors, electrified both poſitively or both negatively, to be preſented towards, and to be gradually brought near, each other; it will appear by two annexed electrometers, that the nearer thoſe two conductors come to each other, the more their intenſities will increaſe; which ſhews, that either of the two conjugate conductors has a much leſs capacity now, than when it was ſingly inſulated, and out of the influence of the other.

Secondly, let the preceding experiment be repeated, with this variation only, viz. that one of the flat conductors be electrified poſitively, and the other negatively: the effects then will be juſt the reverſe of the preceding; viz. the intenſities of their electricities will be diminiſhed, becauſe their capacities are increaſed, the nearer the conductors come to each other.

Let us now apply the explanation of this laſt experiment to that of bringing an electrified metal plate towards an uninſulated conducting plane; for as this plane acquires a contrary electricity by the vicinity of the electrified plate, it follows that the intenſity of the electricity of the metal plate muſt be diminiſhed, and in the ſame proportion its capacity is increaſed; conſequently the metal plate in that caſe may receive a greater quantity of electricity.

This property may be rendered ſtill more evident, by inſulating the conducting plane whilſt the electrified plate is very near it, and afterwards ſeparating them; for then both the metal plate and the conducting plane (which may be called the *inferior* plane) will be found electrified, but poſſeſſed of contrary electricities, as may be aſcertained by electrometers.

If the inferior plane be inſulated firſt, and then the electrified plate be brought over it, then the latter will cauſe an endeavour in the former to acquire a contrary electricity, which however the inſulation prevents from taking

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* *Rozier's Journ.* for 1780.

taking place ; hence the intenſity of the electricity of the plate is not diminiſhed, at leaſt the electrometer will ſhew a very little and almoſt imperceptible depreſſion, which is owing to the imperfection of the inſulation of the inferior plane, and to the ſmall rarefaction and condenſation of the electric fluid, which may take place in different parts of the ſaid inferior plane. But if in this ſituation the inferior plane be touched, ſo as to cut off the inſulation for a moment, then it will immediately acquire the contrary electricity, and the intenſity in the metal plate will be diminiſhed.

If the inferior plane, inſtead of being inſulated, were itſelf a non-conducting ſubſtance, then the ſame phenomena would happen, viz. the intenſity of the electrified metal plate laid upon it would not be diminiſhed. This, however, is not always the caſe ; for if the ſaid inferior non-conducting plane be very thin, and be laid upon a conductor, then the intenſity of the electrified metal plate will be diminiſhed, and its capacity will be increaſed by being laid upon the thin inſulating ſtratum, becauſe, in that caſe, the conducting ſubſtance which ſtands under the non-conducting ſtratum acquiring an electricity contrary to that of the metal plate, will diminiſh its intenſity, &c. and the inſulating ſtratum will only diminiſh the mutual action of the two atmoſpheres, more or leſs, according as it keeps them more or leſs aſunder.

The intenſity or electric action of the metal plate, which diminiſhes gradually as it is brought nearer and nearer to a conducting plane not inſulated, becomes almoſt nothing when the plate is nearly in contact with the plane, the compenſation or accidental balance being then almoſt perfect ; hence if the inferior plane only oppoſes a ſmall reſiſtance to the paſſage of the electricity (whether ſuch reſiſtance be occaſioned by a thin electric ſtratum, or by the plane's imperfect conducting nature, as is the caſe with dry wood, marble, &c.) that reſiſtance, and the interval, however ſmall, that is between the two planes, cannot be overcome by the weak intenſity of the electricity of the metal plate, which on that account will not dart any ſpark to the inferior plane (except its electricity were very powerful, or its edges not well rounded) and will rather retain its electricity ; ſo that, being removed from the inferior plane, its electrometer will nearly recover its former height. Beſides, the electrified plate may even come to touch the imperfectly conducting plane, and may remain in that ſituation for ſome time : in which caſe the intenſity being reduced almoſt to nothing, the electricity will paſs to the inferior plane exceedingly ſlowly.

But the caſe will not be the ſame, if, in performing the experiment, the electrified metal plate be made to touch the inferior plane edgewiſe ; for then its intenſity being greater than when laid flat, as it appears by the electrometer, the electricity eaſily overcomes the ſmall reſiſtance, and paſſes to the inferior plane, even acroſs a thin electric ſtratum ; becauſe the electricity of one plane is balanced by that of the other, only in proportion to the quantity of ſurface which they oppoſe to each other within a given diſtance ; whereby, when the metal plate touches the other plane in flat and ample contact, its electricity is not diſſipated.

Hitherto we have conſidered in what manner the action of electric atmoſpheres muſt modify the electricity of the metal plate in various ſituations. We muſt now conſider the effects which take place when the electricity is communicated to the metal plate whilſt ſtanding upon the imperfectly conducting plane ; however the explanation of this eaſily follows from what has been ſaid above. Suppoſe, for inſtance, that a Leyden phial or a conductor were ſo weakly electrified, that the intenſity of its electricity were only of half a degree, or even leſs ; if the metal plate, when ſtanding upon the proper plane, were touched with that phial or conductor, it is evident that either of them would impart to it a quantity of its electricity, proportional to the plate's capacity, viz. ſo much of it as would make the intenſity of the electricity of the plate equal to that of the electricity in the conductor or phial, ſuppoſed of half a degree ; but the plate's capacity, now that it lies upon the proper plane, is above 100 times greater than if it ſtood inſulated in the air ; or, which is the ſame thing, it requires 100 times more electricity in order to ſhew the ſame intenſity ; therefore, in this caſe, it muſt acquire upwards of a hundred times more electricity from the phial or conductor. It naturally follows, that when the metal plate is afterwards removed from the proper plane, its capacity being leſſened ſo as to remain equal to the hundredth part of what it was before, the intenſity of its electricity muſt become of 50° ; ſince, agreeably to the ſuppoſition, the intenſity of the electricity in the phial or conductor was of half a degree *.

Having premiſed thus much reſpecting the *capacity* of conductors, we ſhall now proceed to deſcribe Signior Volta's method of rendering ſenſible minute degrees of electricity.

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Deſcription of Volta's condenſers.

His method, in ſhort, is to communicate the otherwiſe unobſervable quantity of electricity to the metallic plate of an electrophorus, while ſtanding on an imperfectly inſulating plane ; for the capacity of the metallic plate being thus augmented, it will acquire a much greater quantity of electricity than if it ſtood completely inſulated in the air, and when it is again ſeparated from the plane its capacity will be diminiſhed ; conſequently, its electricity increaſing at the ſame time, the intenſity of this will be rendered manifeſt either by ſparks or by means of a delicate electrometer.

The particulars neceſſary to be kept in view in this method, are the following. The metal plate muſt be at leaſt ſix inches in diameter, with the edge well rounded, and having a varniſhed glaſs handle, or, inſtead of the glaſs, three ſilken ſtrings. The inferior plane muſt be of a very imperfect conducting nature, as dry marble, very dry and ſlightly varniſhed wood, a common piece of wood covered with oiled ſilk, or ſuch like ſubſtance ; but let the ſubſtance be what it will, its ſurface muſt be very ſmooth, and ſuch as to coincide as well as poſſible with the ſurface of the metal plate ; on which account, if a marble ſlab be choſen for the inferior plane, it will be proper to fit the metal plate to that of the iron, by grinding one againſt the other. What Mr Cavallo found to be very fit for this purpoſe was a paper drum, conſiſting of a common wooden hoop, ſuch as are uſed for barrels, over which a piece of thick writing paper was paſted, and on the back of which he paſted a piece of tin-foil. The upper ſurface of the paper was varniſhed only once with ſhell-lac

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* *Cavallo's Electricity*, vol. ii.

diſſolved in alcohol or ſpirit of wine. This ſort of plane has many advantages, viz. it is eaſily made, and from its lightneſs is very portable; its ſurface is perfectly plane, excepting when the hoop is not very ſtrong, for then the contraction of the paper has power ſufficient to warp it; and laſtly, as the thickneſs of the paper and of the varniſh may be varied at pleaſure, and very eaſily, the plane may be rendered of any required degree of conducting power.

Having ſuch a ſemi-conducting plane and metallic plate properly conſtructed, the former is to be laid upon a table, and the latter is to be placed upon it, taking care that the inferior plane be not excited by any degree of friction. If the ſurface of the inferior plane ſhould have acquired any electricity by accidentally rubbing it, &c. the beſt way of freeing it of that electricity is to paſs it two or three times over the flame of a candle. Now the metallic plate is to be ſtruck five or ſix times with the corner of a dry handkerchief, a piece of dry flannel or paper, &c.; then it is to be raiſed from the inferior plane by means of its inſulating handle, and preſented to an electrometer, when it will be found ſenſibly electrified. If the metallic plate be ſtruck while it is not in contact with the ſemi-conducting plane, it will be found either to poſſeſs no electricity or an incomparably ſmaller degree than it acquires in the other mode.

By this means electricity may be obtained from ſubſtances which could hardly be ſuppoſed electrified, and that not only in ſufficient quantity to aſcertain its quality, but even ſufficient to afford ſparks. Signior Volta has given to this apparatus the name of *condenſing apparatus*.

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Mr Cavallo's improvement of the condenſer.

Mr Cavallo, obſerving that in ſtroking the metallic plate, in order to obtain electricity from various ſubſtances, and eſpecially from the hand, the plate was often moved ſo as to occaſion ſome friction on the inferior plane, whereby this was excited, and conſequently the reſult of the experiment rendered precarious, thought of the following method of preventing ſuch motion.

Upon a varniſhed glaſs handle he cemented a braſs tube about ſix inches long and three-fourths of an inch in diameter, from the extremity of which proceeded a fine flexible wire about 14 inches long. Now, when the metallic plate was ſituated upon the inferior plane, he held the glaſs handle of the braſs tube with his left hand, in ſuch a manner as that the end of the wire might touch the plate, the reſt remaining in the air. Sometimes, in order to make a better contact, the end of the above-mentioned wire was put into a hole purpoſely made in the edge of the plate. In this diſpoſition of the apparatus, the ſubſtances to be tried are ſtroked upon the braſs tube, and the electricity produced by them is conveyed to the metallic plate by the wire, which being fine and flexible, communicates no motion to the plate.

Another improvement of Mr Cavallo's conſiſts in rendering ſenſible degrees of electricity ſtill more minute than thoſe which may be diſcovered by the condenſing apparatus.

Notwithſtanding the great ſenſibility of *Volta's condenſer*, yet ſometimes the electricity acquired by the metallic plate from ſome ſubſtances was ſo ſmall as not to affect an electrometer ſufficiently to aſcertain its quality, or even its exiſtence; hence it naturally occurred to Mr Cavallo, that for the ſame reaſon for which the metallic plate of the *condenſing apparatus* manifeſted ſuch minute degrees of electricity as could not be otherwiſe obſerved, another ſmaller plate, or ſmall condenſing apparatus, might be employed to render the weak electricity of the large metallic plate ſenſible. Accordingly, he conſtructed a ſmall plate of about the ſize of a ſhilling, having a glaſs handle covered with ſealing-wax; and when the large metallic plate ſeemed to be ſo weakly electrified as not to affect an electrometer ſenſibly, he placed the ſmall plate upon the inferior plane, and touched it with the edge of the large plate; then, after removing the ſmall plate, he took up the ſmall one from the plane, holding it by the extremity of the glaſs handle, and preſented it to the electrometer, which was generally ſo much affected by it as to diverge to its utmoſt limits.

In this manner Mr Cavallo often obtained electricity more than ſufficient for aſcertaining its quality, from a ſingle ſtroke of the corner of a handkerchief; viz. the large plate being placed upon the proper plane, was ſtroked once; then being removed and preſented to an electrometer, it appeared not electrified; but by touching the ſmall plate with the edge of it, that ſmall plate acquired thereby electricity ſufficient to make an electrometer diverge.

When this ſecondary condenſing apparatus is uſed, care muſt be taken to hold the large plate almoſt vertically while the ſmall plate is touched by it. There is no need of having another inferior plane for the ſmall plate, the large one being ſufficient for both; for immediately after taking up the large plate, weakly electrified, with one hand, you lay down the ſmall plate, &c.

The ſmall quantity of electricity that can be diſcovered by this means is really ſurpriſing, and there is hardly any ſubſtance, excepting the metals, or thoſe which cannot be ſubjected to trial, as water and other fluids, which will not produce ſome electricity when rubbed or ſtroked againſt the large plate of the condenſing apparatus, and that electricity is afterwards condenſed by being communicated to the ſmall plate.

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Bennet's doubler.

The diſcovery of Volta's *condenſer* led to a diſcovery no leſs important, the *doubler*, for which we were firſt indebted to the Reverend Abraham Bennet of Wirkſworth, though the inſtrument has been much improved by Mr Nicholſon and Mr Read.

Plate CXCI.

The doubler in its firſt and ſimpleſt form conſiſted of three parts, which are repreſented at fig. 85. Plate CXCI. viz. a poliſhed braſs plate A, with an inſulating handle fixed in its centre; a ſimilar plate B with an inſulating handle fixed in its periphery, and the cap of Bennet's gold-leaf electrometer C, which ſerves as a third plate. The two plates A and B are varniſhed on the under ſide, and the handles are made of mahogany fixed to the plates by means of glaſs nuts covered with ſealing-wax.

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Manipulation of the doubler.

The method of demonſtrating the preſence of electricity by means of this apparatus is as follows. Suppoſe that we have to examine the electricity of the plate C.

1. Place B upon C, and communicate ſome electricity to the latter, while the plate B is touched with the finger. The conſequence will be that C will receive a greater degree of electricity than it would have been capable of acquiring if B had not been preſent.

2. Remove the communication from C, and take the finger from off B, then raiſe this latter by its inſulating handle, and B and C will exhibit the oppoſite ſtates of electricity more ſtrongly than when they are in contact.

3. Place A upon B, and touch A with the finger. The conſequence will be that A will receive a portion of electricity of a ſtate oppoſite to that of B, or A will be in the ſame ſtate of electricity with C.

4. Place B upon C, and touch B with the finger as before, and at the ſame time apply A edgeways to C. In this ſituation, A will communicate the greateſt part of its electricity to C.

5. Remove A, take the finger from B, and raiſe B from C. The oppoſite ſtates of electricity in B and C, will now be ſtronger than before, on account of the additional electricity afforded by A.

6. Place A upon B again, as in the third ſtage of the proceſs, and repeat the ſubſequent manipulations. In each of them the intenſity of the electricity is ſuppoſed to be doubled, and by proceeding in this manner for a certain time, the electricity originally communicated to C, though at firſt too ſmall to affect the ſtrips of gold leaf, will at laſt become ſufficiently ſenſible to produce a conſiderable divergence of them.

249 Moveable doubler by Dr Darwin.

Though the above proceſs is ſufficiently ſimple and evident, yet it requires to be learned, and takes up a certain time for its performance. It was therefore deſirable that an inſtrument ſhould be formed which might complete this ſeries of operations by a very ſimple mechanical movement. The firſt inſtrument conſtructed with this view was contrived by Dr Darwin, and was ſhown to Mr Nicholſon in the month of December 1787. This inſtrument conſiſted of four metallic plates, two of which were moveable by wheel-work into poſitions which required them to be touched by the hand in order to produce the effect. It appeared to Mr Nicholſon that the whole operation, including the touching, might be done by a ſimple combination without wheel-work by the direct rotation of a winch. This was ſoon afterwards effected, and communicated by him to the Royal Society in 1788. Mr Nicholſon's deſcription of his *revolving doubler*, was firſt printed in the 78th volume of the Philoſophical Tranſactions, and has been reprinted by Mr Nicholſon in his Philoſophical Journal for May 1800, from which we have copied it.

250 Nicholſon's revolving doubler. Plate CXCI.

Fig. 86. repreſents the apparatus of the doubler ſupported on a glaſs pillar $6\frac{1}{2}$ inches long. It conſiſts of the following parts. Two fixed plates of braſs, A and C, are ſeparately inſulated and diſpoſed in the ſame plane, ſo that a revolving plate B may paſs very near them, without touching. Each of theſe plates is two inches in diameter; and they have adjuſting pieces behind, which ſerve to place them accurately in the required poſition. D is a braſs ball, likewiſe of two inches diameter, fixed on the extremity of an axis that carries the plate B. Beſides the more eſſential purpoſe this ball is intended to anſwer, it is ſo loaded within on one ſide, that it ſerves as a counterpoiſe to the revolving plate, and enables the axis to remain at reſt in any poſition. The other parts may be diſtinctly ſeen in fig. 87. The ſhaded parts repreſent metal, and the white repreſent varniſhed glaſs. ON is a braſs axis, paſſing through the piece M, which laſt ſuſtains the plates A and C. At one extremity is the ball D already mentioned; and the other is prolonged by the addition of a glaſs ſtick, which ſuſtains the handle L and the piece GH ſeparately inſulated. E, F, are pins riſing out of the fixed plates A and C, at unequal diſtances from the axis. The croſs-piece GH, and the piece K, lie in one plane, and have their ends armed with ſmall pieces of harpſichord-wire, that they may perfectly touch the pins EF in certain points of the revolution. There is likewiſe a pin I, in the piece M, which intercepts a ſmall wire proceeding from the revolving plate B.

The touching wires are ſo adjuſted, by bending, that when the revolving plate B is immediately oppoſite the fixed plate A, the croſs-piece GH connects the two fixed plates, at the ſame time that the wire and pin at I form a communication between the revolving plate and the ball. On the other hand, when the revolving plate is immediately oppoſite the fixed plate C, the ball becomes connected with this laſt plate, by the touching of the piece K againſt F; the two plates, A and B, have then no connection with any part of the apparatus. In every other poſition the three plates and the ball will be perfectly unconnected with each other.

251 Defects of the doubler.

Mr Bennet and Mr Cavallo obſerved, ſoon after the diſcovery of the doubler, that it never fails to exhibit an electric ſtate by the mere operation, without any communication of electricity being previouſly made. Mr Bennet endeavoured to find out a method of depriving the doubler of this inherent electricity, and after a number of trials, he conſidered the following as the beſt mode of anſwering this purpoſe.

252 Mr Bennet's mode of obviating theſe.

He connected the plates A and C together by a wire hooked at each end upon two ſmall knobs on the backs of the plates, the middle of the ſame wire touching the pillar which ſupports the doubler. Another wire was hooked at one end upon the back of the plate B, and at the other end, to the braſs ball which counterbalances this plate. Thus all the plates were connected with the earth, and by turning the handle of the doubler, it might be diſcharged of electricity in every part of its revolution.

After often trying this method of depriving the doubler, Mr Bennet obſerved that its ſpontaneous diſcharge was almoſt always negative. He then touched A and C with a poſitively charged bottle, and turned the doubler till it produced ſparks for a long time together; and after this ſtrong poſitive charge he hooked on the wires as above, and revolved the plate B about a hundred times, which ſo deprived the doubler of its poſitive electricity, that when the wires were taken off, it produced a negative charge at about the ſame number of revolutions which it required before.

The poſitively charged bottle was again applied, and the wires being hooked upon the plates as before, B was revolved only fifty times, yet this was found ſufficient to deprive it of its poſitive charge, and in many experiments five or ſix revolutions were ſufficient; but he never thought it ſafe to ſtop at ſo few, and therefore he generally turned the handle 40 or 50 times between every experiment.

Leſt electricity adhering to the electrometer ſhould obſtruct the above experiments, Mr Bennet did not let it ſtand in contact with the doubler during its revolutions,

lutions, but touched the plate A with the cap of the electrometer, after he ſuppoſed its electricity was become ſufficiently ſenſible; but leſt even this contact ſhould communicate any electricity, he made a cap of ſhell lac for his electrometer, having a ſmall tin tube in the centre, to which the gold leaf was ſuſpended within the glaſs, and a bent wire was fixed to the top which might eaſily be joined to the plate A of the doubler, and thus the gold leaf was more perfectly inſulated, and the electricity could not be diffuſed over ſo large a ſurface. The glaſs which inſulates the plates and croſs piece of the doubler was alſo covered with ſhell lac *.

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Robiſon's propoſal for obviating the errors of the doubler.

Dr Robiſon conceived that Mr Bennet's original doubler might be freed from error as far as was poſſible, by employing a thin ſtratum of air as the intermedium between the three plates. The method which he propoſes for effecting this is very ingenious. 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 may diſturb the experiment.

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Cavallo's collector of electricity.

Mr Cavallo, finding that Mr Bennet's mode of obviating the inconveniences of the doubler did not ſucceed with him, conſtructed a new inſtrument, which he calls a *collector of electricity*, and a deſcription of which was inſerted in the 78th volume of the Philoſophical Tranſactions. It conſiſts of a plate of tin, ſupported by two upright ſticks of glaſs; on each ſide of which plate are two frames of wood covered with gilt paper, which do not touch the tin-plate, but ſtand parallel to it at a little diſtance. Theſe frames are faſtened to the platform of the inſtrument by hinges; ſo that if electricity be communicated to the plate, it will receive a large quantity without any conſiderable intenſity, becauſe its capacity is much augmented by the vicinity of the plane of gilt paper on each ſide. But if theſe planes be thrown back into the horizontal poſition, which is eaſily done by means of their hinges, the electricity, which before was compenſated in the plate, will have its intenſity greatly increaſed. An electrometer connected with this plate will therefore ſhow ſigns of electricity by means of a communication made between a large ſtock of electricity, and the tin-plate in its firſt poſition, though the intenſity of that ſtock may have been too ſmall to have affected the electrometer without this contrivance.

It does not appear, in the author's deſcription of this inſtrument, that it removes the equivocal effect of the doubler; for it is evident that it does not in its ſimple proceſs, enter the province of the doubler in which this effect takes place. The doubler requires ſix or ſeven turns before it will exhibit ſpontaneous electricity; at which period the firſt charge is magnified above twelve thouſand times; but his ſimple inſtrument will ſcarcely exceed one hundred times, and therefore requires the electricity to be one hundred and twenty times as ſtrong as that which cauſes the uncertainty of the doubler. Whence it may be inferred, that the doubler would have acted unequivocally with all ſuch electricities as this inſtrument is capable of exhibiting *.

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Cavallo's multiplier of electricity.

Mr Cavallo has ſince conſtructed another inſtrument, which he calls a *multiplier of electricity*, and which he conſiders as quite free from equivocal reſults.

" The figs. 88. and 89. repreſent this new inſtrument, and they are about two-thirds of the real ſize. QRS is the bottom board, upon which are ſteadily fixed on the glaſs ſticks H, G, two flat braſs plates A and C.—B is a ſimilar braſs plate ſupported by a glaſs ſtick I, which is cemented in a hole made in the wooden lever KL, which moves round a ſteady pin K, that is ſcrewed tight in the bottom board. By moving this lever backwards and forwards, the plate B may be alternately put in the two ſituations repreſented by the figures. N is a thick braſs wire fixed tight into the bottom board. There is a fourth braſs plate D, ſimilar to the other three, which is ſupported not by glaſs, but a wire; and this wire is ſcrewed faſt to an oblong piece of braſs FP, that ſlides in a grove made for the purpoſe in the bottom board QRS; ſo that by applying a finger's nail to the notch on the end F, the ſliding piece FP may be drawn out either entirely or to a certain length, and of courſe the plate D will be removed to any required diſtance from the fixed plate C. I need not ſay any thing particular reſpecting the ſockets of thoſe braſs plates, they being clearly indicated in the figures, excepting only that the ſocket of the plate A reaches as high as the top of it, and ſerves to receive a wire, or other apparatus, on certain occaſions.

The parts of this inſtrument are ſo adjuſted, as that when the lever is in the ſituation of fig. 88. viz. is puſhed as far toward Q as it can go, the plate B comes parallel to the plate A, and about one-twentieth of an inch diſtant. At the ſame time the extremity of the wire OM juſt touches the fixed wire N, and of courſe renders the plate B uninſulated. But as ſoon as the lever begins to be moved towards S, the communication of the plate B with the wire N, or with the ground, becomes interrupted, and B remains inſulated. And when the lever has been moved as far as it can go towards S, the wire M comes in contact with the plate C, as ſhown in fig. 89. Then the two plates B and C communicate with each other, though they are otherwiſe inſulated. The fourth plate D being ſupported by a wire, communicates with the ground; and when the ſliding piece PF is puſhed home, it ſtands parallel to, and at about one-twentieth of an inch from the plate C.

When the inſtrument is ſituated as in fig. 88. if an electrified body be brought into contact with the plate A, this plate will imbibe a great deal more of that electricity than it would otherwiſe, becauſe its capacity is increaſed by the vicinity of the uninſulated plate B, and therefore, if after the communication of that electricity, the plate B, by moving the lever, be removed from that ſituation, and A be made to touch an electrometer, this will be electrified more ſenſibly by it, than it would have been by the contact of the original electrified body itſelf. So far the plate A acts like a condenſer, or collector of electricity. But let us now conſider the inſtrument as a multiplier.

When the plate A has received a ſmall quantity of electricity by the contact of any electrified body whatever, and that body is removed, the plate B being uninſulated and oppoſed to the electrified plate A, will, like the metal plate of an electrophorus, acquire the contrary electricity, by either receiving from, or giving to, the ground ſome electric fluid, according as the

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* *Bennet's New Experiments.*

* *Nicholſon's Jour.* 4to, vol. i.

the plate A happens to be electrified. Thus, ſuppoſe that A has been electrified poſitively, B will become negative, and *vice verſa*. If now the lever be puſhed towards S, the plate B will remain electrified negatively, the communication with the ground being cut off; and when B comes into the ſituation repreſented by fig. 4th, at which time the wire M touches the plate C, the negative electricity of B will go to C, becauſe the capacity of C for holding electricity is conſiderably augmented by the vicinity of the uninſulated plate D. If after this the lever be moved back again to its firſt ſituation, B will be made negative a ſecond time in the ſame manner as before: and by puſhing the lever again towards S, that ſecond charge of negative electricity will be communicated from B to C; and thus, by repeating the operation, which conſiſts in merely moving the lever backwards and forwards, a conſiderable quantity of negative electricity will be accumulated upon C.

In fact, the action of this inſtrument reſembles very much that of an electrophorus; for the plate A may repreſent the excited reſinous plate, B may repreſent the metal plate of the electrophorus, and C is a kind of reſervoir, into which the ſucceſſive charges of the plate B are collected.—When a number of thoſe charges or portions of electricity has been communicated to C, if the ſliding piece FP be drawn out about an inch, and of courſe the plate D be removed to the like diſtance from the plate C, the capacity of the plate C will thereby be much diminiſhed: and therefore if an electrometer be brought into contact with it, the electricity will be manifeſted: whereas the electricity originally communicated to the plate A, could not have affected an electrometer in any ſenſible degree.

In uſing this inſtrument, 30 or 40 additions of electricity are the utmoſt number practicable; for after that number the augmentation of the charge upon C will not go any farther; the limit of which is, when the charge of C is increaſed to ſuch a degree, as to leave a portion of electricity upon B, equal to that portion which B can receive from the action of A.

In this caſe, let C touch an electrometer as mentioned above, and if the electrometer does not diverge, proceed to a ſecond proceſs; for though its pendulums do not diverge, yet ſome electricity remains in them, which muſt not be diſturbed, as it will help the effect of the ſecond operations, which is as follows: Puſh in the ſlider FP, and go on moving the lever backwards and forwards as before, by which means, after a certain number of additions, the plate C will acquire a ſecond charge, about as high as the former: and if then the ſlider FP be pulled out, and C brought into contact with the ſame electrometer, the divergency of the pendulums, which before was either not at all or hardly perceptible, will thereby be rendered more conſpicuous: and thus it may be increaſed ſtill farther by a third and a fourth operation. But if, notwithſtanding thoſe repeated operations, the electrometer ſhould be found not to diverge, the quantity of electricity may ſtill be augmented by another method, which is, by communicating that little electricity of C to the plate A of another inſtrument of the ſame ſort, and proceeding with that in the manner already deſcribed *."

256 In Nicholſon's Journal for September 1804, is a paper by Mr W. Wilſon, containing a deſcription of an inſtrument which Mr Wilſon calls a *compound condenſer of electricity*, and which he conſiders as an improvement on Mr Cavallo's *multiplier*, anſwering the purpoſe of a condenſer, a ſingle and double *multiplier*, and a *doubler*. The inſtrument is very complicated, containing no leſs than ſix plates. Like all complicated inſtruments of this kind, it is of courſe ſubject to error from its own ſpontaneous electricity.

257 Nicholſon's ſpinning condenſer.

Mr Nicholſon has conſtructed an inſtrument for aſcertaining ſmall degrees of electricity, without, as he ſays, a poſſibility of equivocal reſult. This inſtrument he calls the *ſpinning condenſer*, and it is thus deſcribed in his Journal for April 1797.

Plate CXCI.

" Fig. 90. repreſents a vertical ſection of the inſtrument. A is a metallic vaſe, having a long ſteel axis which paſſes through a hole in the ſtand H at K, and reſts on its pointed end in an adjuſtable ſocket at C. The uſe of the vaſe is, by its weight, to preſerve, for a conſiderable time, the motion of ſpinning which is given by the finger and thumb applied to the nob at the top of the inſtrument. The ſhaded parts D and E repreſent two circular plates of glaſs nearly 1½ inch in diameter. The upper plate is fixed to the vaſe, and revolves with it; the lower is fixed to the ſtand. In the lower plate are inſerted two metallic hooks, diametrically oppoſite each other, at F and G. They are cemented into holes drilled in the edge of the glaſs, which is near two-tenths of an inch thick. In the upper plate are inſerted in the ſame manner two ſmall tails of the fine flatted wire uſed in making ſilver lace. Theſe tails are bended down ſo as to ſtrike the hooks in the revolution, but in all other poſitions they remain freely in the air without touching any part of the apparatus. At C is a ſcrew, which by raiſing or lowering the vaſe keeps the faces of the glaſs plates from each other at whatever diſtance may be required. The faces of the glaſs plates which are oppoſed to each other are coated with ſegments of tin-foil, as repreſented, fig. 91 and 92, the latter of which repreſents the upper plate. Each of the tails communicates with the tin-foil coating to which it is contiguous, as does alſo the hook F with that coating of the lower plate neareſt to it. But the hook G is entirely inſulated from the whole apparatus, and is intended to communicate only with the electrified body or atmoſpherical conductor L. The lower coating neareſt to G is made to communicate permanently with the ſtand H, and conſequently with the earth.

In this ſituation, ſuppoſe the motion of ſpinning to be given to the apparatus, and the effects will be theſe: One of the tails will ſtrike the hook G, by which means the upper coating annexed to that tail will aſſume the electric ſtate of L by communication. But this ſtate, on account of the proximity of the lower uninſulated plate to which it is, at that inſtant, directly oppoſed, will be as much ſtronger than that of L, as a charge exceeds ſimple electrization. The tail G with its plate or coating proceeds onward, and after half a revolution arrives at the ſituation to touch the hook F. The upper coating, the lower on the ſide of F, the hook F itſelf, and the tail V, muſt then conſtitute one jointly inſulated metallic maſs, in which no charge ſubſiſts, but which is ſimply electrified by the whole charge received

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* Cavallo's *Electricity*, vol. iii.

received at G. And of this maſs the ſurfaces of the plates themſelves, conſtituting the electric well of Franklin, will throw out all their electricity to the hook and tail. But the coating and its tail inſtantly paſs round, leaving F electrified, and proceed to bring another charge from G and depoſit it as before. The balls at F are therefore very ſpeedily made to diverge. It is ſcarcely neceſſary to remark, that the two upper coatings do nothing more than double the ſpeed of the operation; one of the tails being employed in collecting, while the other is depoſiting; and that the gold-leaf electrometer may be advantageouſly ſubſtituted for the cork-balls.

The inſtrument I cauſed to be made was five inches high. The receiving ſide G was connected with a coated jar of four ſquare feet coating, and the giving ſide F was connected with Bennet's gold-leaf electrometer. The electrometer was rendered as ſtrongly poſitive as it was capable of being, and the jar was rendered negative, by giving it as much of that power as was produced by drawing a common ſtick of ſealing-wax once through the hand. In this ſtate the jar was incapable of attracting the fineſt thread. The vaſe was then made to ſpin; and the effect was, that the leaves of the electrometer firſt gradually collapſed, and then in the ſame manner gradually opened, and ſtruck the ſides of the glaſs of the electrometer with negative electricity. The experiment was renewed and repeated with every requiſite variation."

258 Three general methods of aſcertaining ſmall degrees of electricity;

To conclude, the methods of aſcertaining minute degrees of electricity may be reduced to three.

259 By a delicate electrometer;

1. If the abſolute quantity of electricity be ſmall and pretty much condenſed, as that produced by a ſmall tourmaline when heated, or by a hair when rubbed, the only effectual method of manifeſting its preſence, and aſcertaining its quality, is to communicate it to a very delicate electrometer, i. e. one that is very light and has no great extent of conducting ſurface.

260 By the collector, multiplier, or condenſer;

2. When we wiſh to aſcertain the preſence of a conſiderable quantity of electricity, which is diſperſed, or expanded into a great ſpace, and is little condenſed, ſuch as the conſtant electricity of the atmoſphere in clear weather, or ſuch as the electricity which remains in a large Leyden phial after the firſt or ſecond diſcharge; this may be beſt aſcertained by means of Cavallo's *collector* or *multiplier*, or by the *condenſer* with Cavallo's improvement of the ſmall plate.

261 By one of the plates of the doubler and a delicate electrometer.

3. When the electricity to be aſcertained is neither very conſiderable in quantity nor much condenſed, ſuch as the electricity of the hair of certain animals, of the ſurface of chocolate when cooling, &c. In this caſe the beſt method is to apply a metallic plate furniſhed with an inſulating handle, ſuch as one of the plates of the doubler, to the electrified body, and to touch the plate with a finger while it remains for ſome time in this ſituation; which done, the plate is to be removed and brought near a ſenſible electrometer; or its electricity may be communicated to the plate of a ſmall condenſer, by which it will be rendered more conſpicuous. In this operation care muſt be taken not to bring the plate too near the body whoſe electricity is to be examined, leſt the friction, likely to happen between the plate and the body, ſhould produce ſome electricity, the origin of which might be attributed to ſome other cauſes.

CHAP. XIV. *Miſcellaneous and additional Experiments and Obſervations.*

262 Nicholſon's improvement of Bennet's electrometer.

MR Nicholſon, in his Journal for September 1797, propoſes what appears to be a valuable improvement in Bennet's electrometer.

"There are, (ſays he) two particulars in which this excellent inſtrument appears capable of improvement: the firſt, to render it portable, without danger to the gold-leaf, and the ſecond to expreſs its various degrees of electrization by a ſcale of diviſions.

I have reflected much on the probable means of ſecuring the gold-leaf from fracture by carriage, but hitherto with little proſpect of ſucceſs. There was ſome hope that a ſingle ſlip of this gold might be preſerved in a ſheath or box, with its ſides very nearly in contact; but when I placed ſuch a ſlip upon a gilded piece of wood of the ſame ſuperficial dimenſions, to which it was faſtened at one end, its flexibility was ſuch that the leaf very readily ſlided along the ſurface of the wood, and became full of folds, by inclining the faſtened end a very few degrees lower than the other extremity. There was ſtill leſs immediate expectation that the ſlips could be actually and repeatedly confined between two leaves or cuſhions, as in the book of the gold-beaters, without their being broke by continual agitation. To this, however, my attention will probably be directed when I may again reſume this object. In the mean time, I recommend it to other philoſophers, as a very deſirable improvement in the mineralogical apparatus, and ſhould rejoice to be anticipated by their ſucceſsful reſearches.

The weight of one ſlip of gold-leaf, in the electrometer of Bennet, is about 1-600th part of a grain; but this, as well as the ſenſibility of the inſtrument, muſt vary, not only from the figure and dimenſions of the piece, but the nature and thickneſs of the gold itſelf *. It ſeemed, therefore, unneceſſary to endeavour to render two of theſe inſtruments comparable with each other. All that could be done was, to diſtinguiſh the different intenſities as ſhewn by the divergencies of the leaf; or, as I have taken it, the diſtances at which they ſtrike a pair of uninſulated metallic bars. In Plate CXCIII. fig. 93. A repreſents the inſulated metallic cap, from which, at C, depend the two narrow pointed ſlips of gold-leaf. BB is the glaſs ſhade, which ſerves to ſupport the cap, and defend the leaves from the motion of the ſurrounding air. DD are two flat radii of braſs, which open and ſhut by means of one common axis, like a pair of compaſſes. By a contrivance of ſprings, they are diſpoſed to open when left at liberty; but the micrometer ſcrew E ſerves to draw a nut, which has two ſteel bars, with a claw at the end of each, that enters into a correſpondent ſlit, in two ſmall cylindrical pieces, to which the radii are fixed reſpectively. This apparatus is ſeen in another poſition in fig. 94. KL repreſents a piece of braſs, which ſerves as the frame for the work, and fits the lower ſocket of the electrometer, FF, fig. 3. In this the letters IH indicate the cylindrical pieces which carry the radii, and are ſeen from beneath. On the ſide of the nut G, one of the ſteel drawing pieces is ſeen; the other being on the oppoſite ſide, and conſequently not viſible. Towards L appear the two re-action ſprings. The other parts require no verbal deſcription.

Plate CXCIII.

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* *Phil. Journ.* i. 333.

In the common conſtruction of the gold-leaf electrometer, there are two pieces of tin-foil paſted on oppoſite parts of the internal ſurface of BB; againſt which the gold-leaf ſtrikes when its electricity is at the maximum. If the radii DD be left at the greateſt opening, our inſtrument does not then differ from that in common uſe. But if the divergence produced by the contact of an atmoſpheric conductor, or any other ſource of electricity, be ſo ſmall as to render it doubtful whether the leaves be electrified or not, the radii may then be brought very gradually together by means of the ſcrew, until the increaſed divergency from their attractive force be ſufficient to aſcertain the kind of electricity poſſeſſed by the leaves. In this and all other caſes, the diviſion on the micrometer head, which ſtands oppoſite the fixed index, at the time the leaves ſtrike the radii, will ſhew the greater or leſs degree of intenſity.

263 His obſervations on the glaſs caſe of this inſtrument.

In his Journal for January 1799, he has the following remarks on the glaſs caſe of this inſtrument.

"Under all the uncertainties concerning the place occupied by the electric charge of coated glaſs, though it may ſeem unfair to make any inference reſpecting glaſs which is uncoated, yet, upon the whole, there appears to be a probability that the interpoſition of naked glaſs may impede the action of electrified bodies. This queſtion more immediately points at the tube in which the gold-leaf electrometer of Bennet is incloſed. To determine whether the tube of the electrometer does affect the electric ſtate of the included leaf, either by compenſation or otherwiſe, I took a piece of window-glaſs eighteen inches long, two inches wide and one-twentieth of an inch thick, which I cleaned very well, and then paſſed it ſeveral times through the hot air over the flame of a candle. In this ſtate one end of the glaſs was laid gently upon the electrified plate of Bennet's electrometer, and then ſuddenly raiſed by a turn of the wriſt. It was ſcarcely poſſible to diſcern that the leaves were at all affected; but when the electrometer was in the plus ſtate a very ſlight collapſion was produced by raiſing the glaſs, and the contrary effect was produced when the electrometer was negative. Some days afterwards the experiment was repeated, after the gold-leaf had been changed for other pieces, which were very pointed and delicate in their movements. The reſult was, that the glaſs was always ſhewn by the electrometer to be in a weak poſitive ſtate; and, when the electricity of the electrometer was made plus, the collapſion was equal to the divergence when it was minus.

In making theſe experiments I had previouſly ſuppoſed that the influence of the metallic ſtate of the electrometer would produce ſomewhat of the nature of a charge upon the glaſs; and conſequently that the intenſity of the leaves would have been diminiſhed during the exiſtence of that charge; and alſo, that in ſuch a caſe the action of the metal through the glaſs would be ſubject to the ſame diminution as in the ſeries of jars. But as the glaſs did not appear to act in this manner, it ſeems proper to conclude that clean glaſs does not affect the electric ſtate of bodies by its vicinity, and that the divergence of the balls or the gold-leaf in the electrometers of Cavallo and Bennet is not diminiſhed by the tube which ſurrounds them.

From a variety of experiments it was clearly aſcertained that the metallic coatings, though by their vicinity they may diminiſh the intenſity of the electric ſtate in the leaves, do nevertheleſs increaſe the angle of divergence by their attraction.

When the gold-leaf electrometer is made with a very ſmall tube, its ſenſibility is ſomewhat increaſed by the nearneſs of the coatings; but the chance of rendering it unſerviceable from caſual friction, which excites the glaſs, and cauſes the gold-leaf to ſtick to it, together with the leſs perfect view of the divergence through a tube of ſmall curvature, afford reaſons why a diameter of leſs than an inch ſhould be rejected. Other reaſons of convenience indicate that the diameter of the glaſs ſhould not much exceed this quantity.

I was once induced to think that the conſiderable magnitude of the cap of Bennet's electrometer might render it leſs capable of being acted upon by ſmall quantities of electricity. Experiment did not however give much countenance to this ſuppoſition. By trials with heads of different ſize, the ſmalleſt were found to be rather more ſenſible to extremely minute electricities, and leſs ſo to ſuch as were greater. The influence of very weak electricity may produce the oppoſite ſtate in the whole of a ſmall head, but only in part of a larger; the remaining part of this laſt aſſuming the oppoſite ſtate, and robbing the leaves of part of their intenſity. But in higher electricities the whole of the large head may be urged to give electricity to the leaves, in a quantity which the ſmaller head could not give without acquiring a higher degree of intenſity, and conſequently more ſtrongly reſiſting the deſired proceſs. It appears therefore that the maximum of effect with a given electricity, acting without communication, will not be obtained but by a head of a definite figure and magnitude."

264 Other methods of imitating the planetary motions.

In N° 82. experiment 5. we deſcribed a method of imitating the planetary motions by the motion communicated by the current of air from electrified points; this may be done in various other ways, of which we ſhall only add the following.

1. From the prime conductor of an electric machine ſuſpend ſix concentric hoops of metals at different diſtances from one another, in ſuch a manner as to repreſent in ſome meaſure the proportional diſtances of the planets. Under theſe, and at the diſtance of about half an inch, place a metallic plate, and upon this plate, within each of the hoops, a glaſs bubble blown very thin and light. On electrifying the hoops, the bubbles will be immediately attracted by them, and will continue to move round the hoops as long as the electrification continues. If the electricity is very ſtrong, the bubbles will frequently be driven off, run hither and thither on the plate, making a variety of ſurpriſing motions round their axis; after which they will return to the hoop, and circulate as before; and if the room is darkened, they will all appear beautifully illuminated with electric light.

2. Provide a ball of cork about three quarters of an inch in diameter, hollowed out in the internal part by cutting it in two hemiſpheres, ſcooping out the inſide, and then joining them together with paſte. Having attached this to a ſilk thread between three and four feet in length, ſuſpend it in ſuch a manner that it may

may juſt touch the knob of an electric jar, the outſide of which communicates with the ground. On the firſt contact it will be repelled to a conſiderable diſtance, and after making ſeveral vibrations will remain ſtationary; but if a candle is placed at ſome diſtance behind it, ſo that the ball may be between it and the bottle, the ball will inſtantly begin to move, and will turn round the knob of the jar, moving in a kind of ellipſis as long as there is any electricity in the bottle. This experiment is very ſtriking, though the motions are far from being regular; but it is remarkable that they always affect the elliptical rather than the circular form.

In the table of conductors we have placed *flame*, *ſmoke*, and the *vapour of hot water*. That theſe vapours are conductors may be ſhewn by the following experiments.

265 Flame a conductor.

Exper. 1.—Bring the knobs of two metallic diſcharging rods, communicating the one with the outſide, and the other with the inſide of a charged phial, oppoſite each other, each within an inch of the flame of a candle, ſo that the flame may be in the middle between them. The flame will be ſeen to ſpread on each ſide towards the knobs, and will produce the diſcharge of the jar.

266 Cuthbertſon's mode of diſtinguiſhing the two electricities.

Mr Cuthbertſon has propoſed a method of diſtinguiſhing poſitive from negative electricity by the flame of a candle. He places the flame of a candle exactly in the middle between two metallic balls at the diſtance of four inches from each other, ſo that the centre of the flame is in a line with that of the balls. The balls are about three-fourths of an inch in diameter, and communicate by inſulated wires, the one with the *poſitive* and the other with the *negative* conductor. If the machine be then put in motion, the flame will waver very much, but will ſeem to incline rather to the *negative* than the *poſitive* ball. After turning the machine for about 50 revolutions (if the glaſs be a plate of two feet diameter), the negative ball will begin to grow warm, while the poſitive ſtill remains cold. After 200 revolutions, the negative ball will become too hot to be touched, while the poſitive will continue as cold as at firſt *.

A charged phial may be gradually diſcharged by paſſing it for ſome time backwards and forwards through the flame of a large candle, ſo that the flame may act alternately on the knob and the outſide coating.

267 Smoke and ſteam conductors.

Exper. 2.—Suſpend a cork-ball electrometer about four or five feet above the prime conductor of an electrical machine; then turn the winch very gently, and it will be found that the balls do not diverge. Now place a *green* wax taper juſt blown out in the prime conductor, ſo that its ſmoke may aſcend towards the balls, and theſe will diverge a little with the ſame degree of motion communicated to the machine.

The ſame effect, but in a leſs degree, will be produced if, inſtead of the taper, a veſſel of hot water is placed below the balls, thus ſhewing that *ſteam* is a conductor, though inferior to *ſmoke* in its conducting power.

Theſe experiments are by Mr Henly, and are among ſeveral others related by him in the 64th volume of the Philoſophical Tranſactions. His reaſon for employing a *green* taper, was, that on account of the verdigris which it contained, it occaſioned much ſmoke with little heat.

It has been remarked in the Introduction, that glaſs, though one of the moſt perfect electrics when cold, becomes a conductor when heated red hot. This is proved by the following experiment, which alſo ſhews that other electrics change their nature when heated.

268 Glaſs and other electrics become conductors when much heated.

Take a ſmall glaſs tube of about one-twentieth of an inch in diameter, and above a foot long; cloſe it at one end, and introduce a wire into it, ſo that it may be extended through its whole length: let two or three inches of this wire project above the open end of the tube, and there faſten it with a bit of cork; tie round the cloſed end of the tube another wire, which will be ſeparated from the wire within the tube only by the glaſs interpoſed between them. In theſe circumſtances endeavour to ſend a ſhock through the two wires; i. e. the wire inſerted in the glaſs tube, and that tied on its outſide, by connecting one of them with the outſide, and touching the other with the knob of a charged jar, and you will find that the diſcharge cannot be made, unleſs the tube be broken; becauſe the circuit is interrupted by the glaſs at the end of the tube, which is interpoſed between the two wires. But put that end of the tube to which the wire is tied into the fire, ſo that it may become juſt red hot, then endeavour to diſcharge the jar again through the wires, and you will find that the exploſion will be eaſily tranſmitted from wire to wire, through the ſubſtance of the glaſs, which, by being made red hot, is become a conductor.

In order to aſcertain the conducting quality of hot reſinous ſubſtances, oils, &c. bend a glaſs tube in the form of an arch CEFD, fig. 95. and tie a ſilk ſtring GCD to it, which ſerves to hold it by when it is to be ſet near the fire; fill the middle part of this tube with roſin, ſealing-wax, &c. then introduce two wires, AE, BF, through its ends, ſo that they may touch the roſin, or penetrate a little way in it. This done, let a perſon hold the tube over a clear fire, ſo as to melt the roſin within it; at the ſame time, by connecting one of the wires, A or B, with the outſide of a charged jar, and touching the other with the knob of the jar, endeavour to make the diſcharge through the roſin, and you will obſerve that, while the roſin is cold, no ſhocks can be tranſmitted through it: but it becomes a conductor according as it melts, and when totally melted, the ſhocks will paſs through it very freely.

269 Glaſs and other electrics when powdered become conductors.

The electric power of glaſs may alſo be deſtroyed by reducing the glaſs to powder. This was aſcertained by M. Wilcke †, and Dr Prieſtley ‡; but it has been moſt ſatisfactorily proved by M. Van Swinden, in the following experiments.

Exper. 1.—He covered a caſe of white iron with powdered glaſs, ſo as to form a cake about an inch thick, a foot long, and eight inches broad, and he placed above this cake, another plate of iron ſo as to form a coating. He then attempted to charge this coated plate, but without ſucceſs; he could produce no ſhock.

Exper. 2.—Suppoſing that the conducting power of the glaſs in the above experiment might ariſe from ſome humidity which it had contracted, he dried it in a crucible, and repeated the experiment. In this caſe, it appeared ſlightly electric, ſo long as the machine was worked,

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* *Nicholſon's Journ.* Nov. 1802.

† *Mem. de l'Acad de Suede*, t. xx.

‡ *Hiſt. of Electricity*, p. viii. ſ. 4.

worked, but when this was ſtopped the plate of powdered glaſs no longer affected the electrometer.

Exper. 3.—Into a jar, coated on the outſide, he put a quantity of powdered glaſs, and having furniſhed it in other reſpects like a Leyden phial, he proceeded to examine whether it would receive a charge. He found that it could be completely charged, a proof that the powdered glaſs acted the part of a conductor *.

By ſimilar experiments M. Van Swinden found that flowers of ſulphur acted as a conductor though more imperfectly than powdered glaſs.

270 Velocity of the electric ſhock.

Soon after the diſcovery of the Leyden phial and ſhock produced by it, it became a deſirable object with electricians to aſcertain how far the ſhock might be conveyed, and how long a time would be required to convey it to any conſiderable diſtance.

The French philoſophers were the firſt to appear in this field, but they did little more than excite the Engliſh to go far beyond them in theſe great undertakings. A circuit was made by the former of 900 toiſes, conſiſting of men holding iron wires betwixt each two, through which the electric ſhock was ſenſibly felt. At another time they made the ſhock paſs through a wire two thouſand toiſes in length, that is, near a Paris league, or about two Engliſh miles and a half; though part of the wires dragged upon wet graſs, went over chaſms, hedges, or paliſades and over ground newly ploughed up. Into another chain they took the water of the baſon in the Thuilleries, the ſurface of which was about an acre, and the phial was diſcharged through it.

Mr Monnier the younger, endeavoured to determine the velocity of the electric power; and for this purpoſe made the ſhock paſs through an iron wire of 950 toiſes in length, but he could not obſerve that it ſpent a quarter of a ſecond in paſſing it. He alſo found, that when a wire of 1319 feet, with its extremities brought near together, was electrified, that the electricity ceaſed at one end the moment it was taken off at the other.

271 Experiments on this inquiry by Dr Watſon and his aſſociates.

But all theſe attempts of the French would ſcarcely have deſerved to be mentioned, but that they preceded the greater, the more numerous, and more accurate experiments of the Engliſh. The names of the Engliſh gentlemen, animated with a truly philoſophical ſpirit, and who were indefatigable in this buſineſs, deſerve to be tranſmitted to poſterity.

The principal agent in this ſcene was Dr Watſon. He planned and directed all the operations, and never failed to be preſent at every experiment. His chief aſſiſtants were Martin Folkes, Eſq. preſident of the Royal Society, Lord Charles Cavendiſh, Dr Bevis, Mr Graham, Dr Birch, Mr Peter Daval, Mr Trembley, Mr Elliot, Mr Robins, and Mr Short. Many other perſons, and ſome of diſtinction, gave their attendance occaſionally.

Dr Watſon, who wrote the hiſtory of their proceedings, in order to lay them before the Royal Society, begins by obſerving (what was verified in all their experiments) that the electric ſhock is not, ſtrictly ſpeaking, conducted in the ſhorteſt manner poſſible, unleſs the bodies through which it paſſes, conduct equally well; for that, if they conduct unequally, the circuit is always formed through the beſt conductors, though the length of it be ever ſo great.

The firſt attempt theſe gentlemen made, was to convey the electric ſhock acroſs the river Thames, making uſe of the water of the river for one part of the chain of communication. This they accompliſhed on the 14th and 18th of July of 1747, by faſtening a wire all along Weſtminſter bridge, at a conſiderable height above the water. One end of this wire communicated with the coating of a charged phial, the other being held by an obſerver, who in his other hand held an iron rod, which he dipped into the river. On the oppoſite ſide of the river ſtood a gentleman who likewiſe dipped an iron rod in the river with one hand, and in the other held a wire, the extremity of which might be brought into contact with the wire of the phial.

Upon making the diſcharge, the ſhock was felt by the obſervers on both ſides of the river, but more ſenſibly by thoſe who were ſtationed on the ſame ſide with the machine; part of the electric fire having gone from the wire down the moiſt ſtones of the bridge, thereby making ſeveral ſhorter circuits to the phial, but ſtill all paſſing through the gentlemen who were ſtationed on the ſame ſide with the machine. This was, in a manner demonſtrated by ſome perſons feeling a ſenſible ſhock in their arms and feet, who only happened to touch the wire at the time of one of the diſcharges, when they were ſtanding upon wet ſteps which led to the river *.

Upon this and the ſubſequent occaſions, the gentlemen made uſe of wires, in preference to chains, for this, among other reaſons, that the electricity which was conducted by chains, was not ſo ſtrong as that conducted by wires. This, as they well obſerved, was occaſioned by the junctures of the links not being ſufficiently cloſe, as appeared by the flaſhing and ſnapping at every juncture, where there was the leaſt ſeparation. Theſe leſſer ſnappings being numerous in the whole length of a chain, very ſenſibly leſſened the great diſcharge at the prime conductor.

Their next attempt was to force the electrical ſhock to make a circuit of two miles, at the New-river at Stoke Newington. This they performed on the 24th of July 1747, at two places; at one of which, the diſtance by land was 800 feet, and by water 2000: in the other the diſtance by land was 2800 feet, and by water 8000. The diſpoſition of the apparatus was ſimilar to what they before uſed at Weſtminſter bridge, and the effect anſwered their utmoſt expectations. But, as in both caſes, the obſervers at both extremities of the chain, which terminated in the water, felt the ſhock, as well when they ſtood with their rods fixed into the earth 20 feet from the water, as when they were put into the river; it occaſioned a doubt, whether the ſhock was formed through the windings of the river, or a much ſhorter way by the ground of the meadow: for the experiment plainly ſhewed, that the meadow ground, with the graſs on it, conducted the electricity very well.

By ſubſequent experiments, they were fully convinced, that the electricity had not in this caſe been conveyed by the water of the river, which was two miles in length, but by land, where the diſtance was only one mile; in which ſpace, however, the electric power muſt neceſſarily have paſſed over the New-river twice, have gone through ſeveral gravel pits, and a large ſtubble field †.

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* Van Swinden ſur l'Analogie de l'Electricité et de Magnetiſme, tom. i. p. 43.

* Phil. Tranſ. Abr. vol. x. p. 349, &c.

† Ib p. 360.

I

On

Principles of Electricity illuſtrated by experiment.

On the 28th of July they repeated the experiment at the ſame place, with the following variation of circumſtances. The iron wire was, in its whole length, ſupported by dry ſticks, and the obſervers ſtood upon original electrics; the effect of which was, that they felt the ſhock much more ſenſibly than when the conducting wire had lain upon the ground, and when the obſervers had ſtood likewiſe upon the ground, as in the former experiment.

Afterwards, every thing remaining as before, the obſervers were directed, inſtead of dipping their rods into the water, to put them into the ground, each 150 feet from the water. They were both ſmartly ſtruck, though they were diſtant from each other above 500 feet.

The ſame gentlemen, pleaſed with the ſucceſs of their former experiments, undertook another, the object of which was to determine, whether the electric power could be conveyed through dry ground; and at the ſame time to carry it through water to a greater diſtance than they had done before. For this purpoſe they pitched upon Highbury-barn, beyond Iſlington, where they carried it into execution on the 5th of Auguſt 1747. They choſe a ſtation for their machine almoſt equally diſtant from two other ſtations for obſervers, upon the New-river, which were ſomewhat more than a mile aſunder by land, and two miles by water. They had found the ſtreets of London, when dry, to conduct very ſtrongly, for about 40 yards; and the dry road at Newington about the ſame diſtance. The event of this trial anſwered their expectations. The electric fire made the circuit of the water when both the wires and the obſervers were ſupported on original electrics, and the rods dipped into the river. They alſo both felt the ſhock, when one of the obſervers was placed in a dry gravelly pit, about 300 yards nearer the machine than the former ſtation, and 100 yards diſtant from the river; from which the gentlemen were ſatisfied, that the dry gravelly ground had conducted the electricity as ſtrongly as water.

The laſt attempt of this kind which theſe gentlemen made, and which required all their ſagacity and addreſs in the conduct of it, was to try whether the electric ſhock was perceptible at twice the diſtance to which they had before carried it, in ground perfectly dry, and where no water was near, and alſo to diſtinguiſh, if poſſible, the comparative velocity of electricity, and of ſound.

For this purpoſe they fixed upon Shooter's-hill, and made their firſt experiment on the 14th of Auguſt 1747, a time, when, as it happened, but one ſhower of rain had fallen during five preceding weeks. The wire communicating with the iron rod, which made the diſcharge, was 6732 feet in length, and was ſupported all the way upon baked ſticks; as was alſo the wire which communicated with the coating of the phial, which was 3868 feet long, and the obſervers were diſtant from each other two miles. The reſult of the exploſion demonſtrated, to the ſatisfaction of the gentlemen preſent, that the circuit performed by the electricity was four miles, viz. two miles of wire, and two of dry ground, the ſpace between the extremities of the wires, a diſtance, which, without trial, as they juſtly obſerved, was too great to be credited. A gun was diſcharged at the inſtant of the exploſion, and the obſervers had ſtop watches in their hands, to note the moment when they felt the ſhock; but as far as they could diſtinguiſh, the time in which the electric power performed that vaſt circuit was inſtantaneous.

Principles of Electricity illuſtrated by experiment.

In all the exploſions where the circuit was made of any conſiderable length, it was obſerved, that though the phial was very well charged, yet that the ſnap at the gun-barrel made by the exploſion was not near ſo loud as when the circuit was formed in a room; ſo that a byſtander, ſays Dr Watſon, would not imagine, from ſeeing the flaſh and hearing the report, that the ſtroke, at the extremity of the conducting wire, would have been conſiderable, the contrary of which, when the wires were properly managed, he ſays, always happened.

Still the gentlemen, unwearied in theſe purſuits, were deſirous of aſcertaining, if poſſible, the abſolute velocity of electricity though a certain ſpace; becauſe, though in the laſt experiment, the time of its progreſs was certainly very ſmall, they were deſirous of knowing, ſmall as that time might be, whether it was meaſurable, and Dr Watſon had contrived an excellent method for that purpoſe.

Accordingly, on the 5th of Auguſt 1748, the gentlemen met for the laſt time, at Shooter's-hill; when it was agreed to make an electric circuit of two miles, by ſeveral turnings of the wire, in the ſame field. The middle of this circuit they contrived to be in the ſame room with the machine, where an obſerver took in each hand one of the extremities of the wires, each of which was a mile in length. In this excellent diſpoſition of the apparatus, in which the time between the exploſion and the ſhock could be obſerved with the greateſt exactneſs, the phial was diſcharged ſeveral times; but the obſerver always felt himſelf ſhocked at the very inſtant of making the exploſion. Upon this the gentlemen were fully ſatisfied, that through the whole length of this wire, which was 12,276 feet in length, the velocity of the electric power was inſtantaneous*.

How to ſpin ſealing-wax into threads.

We have noticed the increaſed evaporation from liquids by means of electricity. The following experiment, which is commonly exhibited by lecturers on electricity, is uſually conſidered of the ſame kind.

Stick a ſmall piece of ſealing-wax on the end of a wire, and ſet fire to it. Then put an electrical machine in motion, and preſent the wax juſt blown out at the diſtance of ſome inches from the prime conductor. A number of extremely fine filaments will immediately dart from the ſealing wax to the conductor, on which they will be condenſed into a kind of net-work, reſembling wool.

If the wire with the ſealing-wax be ſtuck into one of the holes of the conductor, and a piece of paper be preſented at a moderate diſtance to the wax, juſt after it has been ignited, on ſetting the machine in motion, a network of wax will be formed on the paper. The ſame effect, but in a ſlighter degree, will be produced, if the paper be briſkly rubbed with a piece of elaſtic gum, and the melting ſealing-wax be held pretty near the paper immediately after rubbing.

If the paper thus painted, as it were, with ſealing-wax, be gently warmed by holding the back of it to the fire, the wax will adhere to it, and the reſult of the experiment will thus be rendered permanent.

A beautiful experiment of the ſame nature is made

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* *Phil. Tranſ. Abr.* vol. x. 272

with camphor. A ſpoon holding a piece of lighted camphor is made to communicate with an electrified body as the prime conductor of a machine, while the conductor continues electrified by keeping the machine in motion, the camphor will throw out ramifications, and appear to ſhoot like a vegetable.

273 To make camphor ſhoot into ramifications.

274 Curious experiment of Profeſſor Lichtenberg.

Soon after the diſcovery of the electrophorus by Signior Volta, an experiment was made with that inſtrument by Profeſſor Lichtenberg of Gottingen, that attracted conſiderable notice. It is thus deſcribed by Mr Cavallo.

The electrophorus, that is, a plate of ſome reſinous ſubſtance, as ſulphur, roſin, gum-lac, &c. is firſt excited, either by rubbing or otherwiſe; then a piece of metal of any ſhape, at pleaſure, as for inſtance, a three-legged compaſs, a piece of braſs tube, or the like, is ſet upon the electrophorus, and to this piece of metal, ſo placed, a ſpark is given, of the electricity contrary ſo that of the plate; this done, the piece of metal is removed, by means of a ſtick of ſealing-wax or other electric, and ſome powder of roſin, kept in a linen bag, is ſhaken upon the electrophorus: this powder will be found to fall about thoſe points upon the plate, which the piece of metal touched, forming ſome radiated appearances, much like the common repreſentations of ſtars; at the ſame time, upon the greateſt part of the plate, that is, beſides thoſe ſtars, there is hardly any powder at all. Now, it is to be remarked, that if the plate be excited negatively, and the ſpark given to the metal ſet upon it is poſitive, the appearance will be as above deſcribed; but if, on the contrary, the plate is poſitive and the ſpark is negative, then the powder of roſin will be found to fall upon thoſe parts of the plate which in the other caſe is left uncovered, and to leave the ſtars clean; in ſhort, it will do juſt the reverſe of what it did in the other caſe; or, in other words, the powder of roſin will be attracted by thoſe parts only of the electrophorus which are electrified poſitively.

275 Method of producing various configurations by electricity.

The configurations produced in the above experiment of M. Lichtenberg appeared ſo curious that they were ſoon imitated by various electricians, particularly by Mr Cavallo and the Reverend Abraham Bennet, inventor of the doubler. The directions given by this laſt gentleman are as follows.

To make red figures, take a pound of raſped Brazil wood: put it into a kettle with as much water as will cover it, or rather more; alſo put in about an ounce of gum arabic and a lump of alum about as big as a large nut; let it boil about two hours, or till the water is ſtrongly coloured; ſtrain off the extract into a broad diſh, and ſet it in an iron oven, where it is to remain till all the water be evaporated, which with me was effected in about twelve hours; but this depends on the heat of the oven, which ſhould not be ſo hot as to endanger its burning. Sometimes I have boiled the ſtrained extract till it was conſiderably inſpiſſated before it was placed in the oven, that it might be ſooner dry.

When it is quite dry but not burnt, ſcrape it out of the diſh, and grind it in a mortar till it be finely pulverized. In doing this, it is proper to cover the mortar with a cloth, having a hole through to prevent the powder from flying away and offending the noſe, and alſo to do it out of doors if the weather be dry and calm, that the air may carry away the powder neceſſarily eſcaping, and which otherwiſe is very diſagreeable. When ground fine, let it be ſifted through muſlin or a fine hair-ſieve, returning the coarſer part into the mortar to be ground again. When the grinding and ſifting are finiſhed, the powder is ready for uſe. The reſinous plate I have moſtly uſed was compoſed of five pounds of roſin, half a pound of bees-wax, and two ounces of lamp-black, melted together, and poured upon a board ſixteen inches ſquare, with ribs upon the edges at leaſt half an inch high, to confine the compoſition whilſt fluid: thus the reſinous plate was half an inch thick, which is better than a thinner plate, the figures being more diſtinct. After the compoſition is cold, it will be found covered with ſmall bliſters, which may be taken out by holding the plate before the fire, till the ſurface be melted, then let it cool again, and upon holding it a ſecond time to the fire, more bliſters will appear; but by thus repeatedly heating and cooling the ſurface, it will at laſt become perfectly ſmooth. Some plates were made ſmaller, and the reſinous compoſition confined to the form of an ellipſis, a circle, or eſcutcheon, by a rim of tin half an inch broad, and fixed upon a board.

The next thing to be done is to prepare the paper, which is to be ſoftened in water, either by laying the pieces upon each other in a veſſel of cold water, or firſt pouring a little hot water upon the bottom of a large diſh, then laying upon it a piece of paper, ſo that one edge of the paper may lie over the edge of the diſh, to remain dry, that it may afterwards be more conveniently taken up. Then pour more hot water upon its upper ſurface. Upon this place another piece in the ſame manner, again pouring on more water, and thus proceed till all the pieces are laid in. By uſing hot water, the paper will be more ſoftened in a few minutes than if it remains in cold water a whole day.

When the figures are to be made, the reſinous plate muſt lie horizontally, whilſt the electricity is communicated, if the experiment requires any thing to be placed upon the plate: but it is convenient afterwards to hang it up in a vertical poſition whilſt the powder is projected, leſt too much powder ſhould fall where it is not required.

A little of the powder may be taken between a finger and thumb, and projected by drawing it over a bruſh; or, which is better, a quantity of powder may be put into the bellows and blown towards the plate. When the figure is ſufficiently covered with powder, let the plate be again laid horizontally upon a table; then take one of the ſoftened papers out of the water by its dry edge, and lay it carefully between the leaves of a book, preſſing the book together, and let it lie in this ſituation about half a minute. Then remove the paper to a dry place in the book, and preſs it again about the ſame time, which will generally be ſufficient to take off the ſuperfluous moiſture. Then take up the paper by the two corners of its dry edge, and place the wet edge a little beyond the figure on the reſinous plate, lowering the reſt of the piece gradually till it covers the figure without ſliding; then lay over it a piece of clean dry paper, and preſs it gently; let it remain a ſhort time, and then rub it cloſer to the plate with a cloth, or, which is better, preſs it down by means of a wooden roller covered with cloth, taking care that the paper be not moved from its firſt poſition. When the paper is ſufficiently preſſed, let it be taken up by its dry edge, and laid upon the ſurface of a veſſel of water with the printed ſide downwards; by this means the ſuperfluous powder will ſink in the water, and the figure will not be ſo liable afterwards to ſpread in the paper. After the paper has remained on the water during a few minutes, take it up and place it between the leaves of a book, removing it frequently to a dry place. If it be deſired that the paper ſhould be ſpeedily dry, let the book-leaves in which it is to be placed be previouſly warmed, and by removing it to ſeveral places it will be dry much ſooner than by holding it near a fire, and without drawing the paper crooked. By the above proceſs, it is obvious, that leather, callico, or linen, as well as paper, may be printed with theſe figures, and the effects of the diffuſion of electricity upon a reſinous plate be exhibited to thoſe who have not leiſure or inclination to perform the experiments †.

The figures repreſented in Plate CXCII. were formed much after Mr Bennet's method.

The apparatus uſed for making them conſiſted only of a common Leyden phial, and a plate of glaſs 15 inches ſquare, covered on one ſide with a varniſh of gum-lac diſſolved in ſpirit of wine, and ſeveral times laid over. The other ſide is covered with tin-foil laid on with common paſte. When it is to be uſed, the glaſs plate is put upon a metallic ſtand, with the tin-foiled ſide laid undermoſt; the phial is to be charged, and the knob drawn over the varniſhed ſide. Thus any kind of figure may be drawn, or letters made, as repreſented in the plate; and from every figure beautiful ramifications will proceed, longer or ſhorter according to the ſtrength of the charge. On ſome occaſions, however, the charge may be too ſtrong, particularly where we wiſh to repreſent letters, ſo that the whole will be blended into one confuſed maſs. The round figures are formed by placing metallic rings or plates upon the electrical plate; and then giving them a ſpark from the electrified bottle, or ſending a ſhock through them. The figures may be rendered permanent by blowing off the looſe chalk, and clapping on a piece of black-ſized paper upon them; or if they are wanted of another colour, they may eaſily be obtained by means of lake, vermilion, roſe-pink, or any of the ordinary colours ground very fine. The eaſieſt way of applying them ſeems to be by a barber's puff bellows.

276 Experiments on the effect produced by electricity on magnetic needles,

We ſhall conclude this part of our article with noticing the effects produced by electricity on magnetic needles.

Theſe may be ſtated in the following propoſition.

An electric ſhock communicates a magnetic power to needles, and frequently reverſes or deſtroys that polarity.

277 by Dr Franklin.

By electricity Dr Franklin frequently gave polarity to needles and reverſed them at pleaſure. A ſhock from four large jars, ſent through a fine ſewing needle, he ſays, gave it polarity, ſo that it would traverſe when laid on water. What is moſt remarkable in theſe electrical experiments upon magnets is, that if the needle, when it was ſtruck, lay eaſt and weſt, the end which was entered by the electric blaſt pointed north; but that if it lay north and ſouth, the end which lay towards the north would continue to point north, whether the fire entered at that end or the contrary; though he imagined that a ſtronger ſtroke would have reverſed the poles even in that ſituation, an effect which had been known to have been produced by lightning. He alſo obſerved, that the polarity was ſtrongeſt when the needle was ſtruck lying north and ſouth, and weakeſt when it lay eaſt and weſt. He takes notice that, in theſe experiments the needle, in ſome caſes, would be finely blued like the ſpring of a watch, by the electric flame; in which caſe, the colour given by a flaſh from two jars only might be wiped off, but that a flaſh from four jars fixed it, and frequently melted the needles. The jars which the doctor uſed held ſeven or eight gallons, and were coated and lined with tin-foil *.

278 by Van Marum.

Dr Van Marum made ſeveral experiments on communicating polarity to needles with his very powerful machine. He and his coadjutor tried to give polarity to needles made of watch ſprings from three to ſix inches in length, and likewiſe to ſteel bars nine inches long, from a quarter of an inch to half an inch broad, and about a line in thickneſs. The reſult was, that when the bar or needle was placed horizontally in the magnetic meridian, whichever way the ſhock entered, the end of the bar that ſtood toward the north acquired the north polarity, or the power of turning towards the north when freely ſuſpended, and the oppoſite end acquired the ſouth. If the bar, before it received the ſhock, had ſome polarity, and was placed with its poles contrary to the uſual direction, then its natural polarity was always diminiſhed, and often reverſed; ſo that the extremity of it, which in receiving the ſhock looked towards the north, became the north pole, &c.

When the bar or needle was ſtruck ſtanding perpendicularly, its loweſt end became the north pole in any caſe, even when the bar had ſome magnetiſm before, and was placed with the ſouth pole downwards. *Cæteris paribus*, the bars ſeemed to acquire an equal degree of magnetic power, whether they were ſtruck whilſt ſtanding horizontally in the magnetic meridian, or perpendicular to the horizon.

When the bar or needle was placed in the magnetic equator, whichever way the ſhock entered, it never gave it any magnetiſm; but if the ſhock was given through its width, then the needle acquired a conſiderable degree of magnetiſm, and the end which lay towards the weſt became the north pole, and the other end the ſouth pole.

If a needle or bar, already magnetic, or a real magnet, was ſtruck in any direction, its power was always diminiſhed. For this experiment, they tried conſiderably large bars, one being 7,08 inches long, 0,26 broad, and 0,05 thick.

When the ſhock was ſo ſtrong in proportion to the ſize of the needle, as to render it hot, then the needle generally acquired no magnetiſm at all, or very little.

Theſe experiments were made with the extraordinary power of a battery compoſed of 135 phials, containing among them about 130 ſquare feet of coated ſurface.

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† *Bennet's new Experiments.*

* *Franklin's Letters.*

PART IV.

THEORY OF ELECTRICITY.

CHAP. I. *A Conciſe View of the Principal Theories of Electricity.*

SECT. I. *Of the Theories of Electricity before the Time of Franklin.*

279 Theory of the early electricians. THE firſt electricians ſuppoſed, that electrical attraction was performed by means of unctuous effluvia emitted by the excited electric. Theſe were ſuppoſed to attach themſelves to all bodies, and to carry back with them thoſe which were not too heavy. For in that age of philoſophy all effluvia were ſuppoſed to return to the body from which they had been emitted, ſince no perſon could otherwiſe account for the ſubſtance not being ſenſibly waſted by the conſtant emiſſion. When theſe light bodies, on which the unctuous effluvia had faſtened, had arrived again at the excited electric, a freſh emiſſion of the effluvia was ſuppoſed to carry them back again. But this effect of the effluvia was not thought of, till electrical repulſion had been ſufficiently obſerved.

When the Newtonian philoſophy had made ſome progreſs, and the extreme ſubtility of light, and other effluvia of bodies, was demonſtrated, ſo that philoſophers were under no apprehenſion of bodies being waſted by continual emiſſion, the doctrine of *the return of effluvia* was univerſally given up, as being no longer neceſſary; and they were obliged to acquieſce in the unknown doctrines of attraction and repulſion, as natural properties of certain bodies, the unknown cauſe of which they ſcarcely attempted to explain.

280 Hypotheſis of Du Faye. Early in the 18th century, M. du Faye diſcovered that there were two ſtates of electricity, or, as he ſuppoſed, two different kinds of electricity, produced when different electrics were excited. "Chance (ſays he) has thrown in my way a principle, which caſts a new light upon the ſubject of electricity. The principle is, that there are two diſtinct kinds of electricity, very different from one another; one of which I call vitreous, the other reſinous electricity. The firſt is that of glaſs, rock cryſtal, precious ſtones, hairs of animals, wool, and many other bodies. The ſecond is that of amber, copal, gum-lac, ſilk, thread, paper, and a vaſt number of other ſubſtances. The characteriſtics of theſe two electricities are, that they repel themſelves, and attract each other. Thus a body poſſeſſed of the vitreous electricity, repels all other bodies poſſeſſed of the vitreous, and on the contrary, attracts all thoſe poſſeſſed of the reſinous electricity. The reſinous alſo repels the reſinous, and attracts the vitreous. From this principle one may eaſily deduce the explanation of a great number of other phenomena; and it is probable that this truth will lead us to the diſcovery of many other things."

This diſcovery of M. du Fay was the origin of a theory of electricity, which is commonly called the *theory of two fluids*, and which we ſhall preſently conſider more at length.

281 Hitherto attraction and repulſion were the only electrical phenomena which had been obſerved; and to the explanation of theſe, the above general theories appeared ſufficiently competent. But when electricity began to ſhew itſelf in a greater variety of appearances, and to make itſelf ſenſible to the ſmell, the ſight, the touch and the hearing; when bodies were not only attracted and repelled, but made to emit ſtrong ſparks of fire, attended with a conſiderable noiſe, a painful ſenſation, and a ſtrong phoſphorical ſmell, electricians were obliged to make their ſyſtems more complex, in proportion as the facts accumulated. It was then generally ſuppoſed that the electric power, which now began to aſſume the name of the *electric fluid*, was the ſame with the chemical principle of fire; though ſome thought it was a fluid *ſui generis*, which very much reſembled that of fire; and others, with M. Boulanger at their head, thought that the electric fluid was nothing more than the finer parts of the atmoſphere, which crowded upon the ſurfaces of electric bodies, when the groſſer parts had been driven away by the friction of the rubber.

282 Electric matter diſcovered to come from the earth. During this time, it was imagined, that the electric matter was produced from the electric body by friction; but by a diſcovery of Dr Watſon's, it became univerſally believed, that the glaſs globes and tubes ſerved only to ſet the fluid in motion, and by no means to produce it. He was led to this diſcovery by obſerving, that, upon rubbing the glaſs tube, while he was ſtanding upon cakes of wax or roſin (in order, as he expected, to prevent any diſcharge of the electric matter upon the floor), the power was, contrary to his expectation, ſo much leſſened, that no ſnapping could be obſerved upon another perſon's touching any part of his body; but that, if a perſon not electrified held his hand near the tube while it was rubbed, the ſnapping was very ſenſible. The event was the ſame when the globe was whirled in ſimilar circumſtances. For, if the man who turned the wheel, and who, together with the machine, was ſuſpended upon ſilk, touched the floor with one foot, the electric fire appeared upon the conductor; but if he kept himſelf free from any communication with the floor, little or no fire was produced.—He obſerved, that only a ſpark or two would appear between his hand and the inſulated machine, unleſs he at the ſame time formed a communication between the conductor and the floor; but that then there was a conſtant and copious flow of the electric matter obſerved between them. From theſe, and ſome other experiments of a ſimilar kind, the Doctor diſcovered what he called the *complete circulation* of the electric matter. When he found, that, by cutting off the communication of the glaſs globe with the floor, all electric operations were ſtopped, he concluded, that the electric fluid was conveyed from the floor to the rubber,

rubber, and from thence to the globe. For the ſame reaſon, ſeeing the rubber, or the man who had a communication with it, gave no ſparks but when the conductor was connected with the floor, he as naturally concluded, that the globe was ſupplied from the conductor, as he had before concluded that it was ſupplied from the rubber.

283
Dr Watſon's theory of afflux and efflux.

From all this he was at laſt led to form a new theory of electricity, namely, that, in electric operations, there was both an *afflux* of electric matter to the globe and the conductor, and likewiſe an *efflux* of the ſame electric matter from them. Finding that a piece of leaf ſilver was ſuſpended between a plate electrified by the conductor, and another communicating with the floor, he reaſons from it in the following manner: "No body can be ſuſpended in equilibrio but by the joint action of two different directions of power; ſo here the blaſt of electric ether from the floor ſetting through it, drives the ſilver towards the plate electrified. We find from hence, likewiſe, that the draught of electric ether from the floor is always in proportion to the quantity thrown by the globe over the gun barrel (the prime conductor at that time made uſe of), or the equilibrium by which the ſilver is ſuſpended could not be maintained." Some time after, however, the Doctor retracted this opinion concerning the afflux and efflux, and ſuppoſed that all the electric phenomena might be accounted for from the exceſs or diminution of the quantity of electric matter contained in different bodies. This is the theory that was more fully explained by Franklin. It has been diſputed whether Dr Watſon or Franklin were the original contriver of this theory. It is poſſible that Watſon may have formed the idea independently of Franklin; but certainly to this latter able and acute philoſopher is due the merit of having framed and applied the hypotheſis of poſitive and negative electricity, which, with ſome modification has been ſince almoſt univerſally adopted.

284
Difficulty concerning the direction of the electric fluid.

One great difficulty with which the firſt electricians were embarraſſed, was to aſcertain the direction of the fluid. At firſt, all electric powers, as we have already obſerved, were ſuppoſed to reſide in the excited globe or glaſs tube. The electric ſpark therefore was imagined to proceed from the electrified body towards any conductor that was preſented to it. It was never imagined that there could be any difference in this reſpect, whether it was amber, glaſs, ſealing wax, or any thing elſe that was excited. This progreſs of the electric matter was thought to be quite evident to the ſenſes; and therefore the obſervation of electric appearances at an inſulated rubber occaſioned the greateſt aſtoniſhment.—In this caſe, the current could not be ſuppoſed to flow both from the rubber and the conductor, and yet the firſt appearances were the ſame. To provide a ſupply of the electric matter, therefore, philoſophers were obliged to ſuppoſe, that, notwithſtanding appearances were in both caſes much the ſame, the electric fluid was really emitted in one caſe by the electrified body, and received by it in the other. But now being obliged to give up the evidence from ſight for the manner of its progreſs, they were at a loſs, whether, in the uſual method of electrifying by excited glaſs, the fluid proceeded from the rubber to the conductor, or from the conductor to the rubber. It was, however, ſoon found, that the electricity at the rubber was the reverſe of that at the conductor, and in all reſpects the ſame with that which had before been produced by the friction of ſealing wax, ſulphur, roſin, &c. Seeing, therefore, that both the electricities were produced at the ſame time, by one and the ſame electric, and by the ſame friction, all philoſophers were naturally led to conclude, that both were modifications of one fluid; though in what manner that fluid was modified throughout the immenſe variety of electric phenomena, was a matter not eaſy to be determined.

285
Abbe Nollet's theory.

On this ſubject the Abbé Nollet adopted the doctrine of *afflux* and *efflux* already mentioned. He ſuppoſed, that, in all electrical operations, the fluid is thrown into two oppoſite motions; that the afflux of this matter drives all light bodies before it by impulſe upon the electrified body, and its efflux carries them back again. He was, however, very much embarraſſed in accounting for facts where both theſe currents muſt be conſidered; as in the quick alternate attraction and repulſion of light bodies by an excited glaſs tube, or other excited electric. To obviate this difficulty, he ſuppoſes that every excited electric, and likewiſe every body to which electricity is communicated, has two orders of pores, one for the emiſſion of the effluvia, and another for the reception of them. M. de Tour improved upon Nollet's hypotheſis, and ſuppoſed that there is a difference between the affluent and effluent current; and that the particles of the fluid are thrown into vibrations of different qualities, which makes one of theſe currents more copious than the other, according as ſulphur or glaſs is uſed. It is impoſſible, however, that ſuppoſitions ſo very arbitrary could be at all ſatisfactory, or received as proper explanations of the electric phenomena.

About this time the Leyden phial was diſcovered; and the extraordinary effects of it rendered the inquiries into the nature of the electric fluid much more general than before. It would be tedious, and indeed impoſſible, to give an account of all the theories which were now invented.

286
Mr Wilſon's theory.

One of the moſt remarkable was that of Mr Wilſon. According to this gentleman, the chief agent in all the operations of electricity, is Sir Iſaac Newton's ether; which is more or leſs denſe in all bodies in proportion to the ſmallneſs of their pores, except that it is much denſer in ſulphureous and unctuous bodies. To this ether are aſcribed the principal phenomena of attraction and repulſion: the light, the ſulphureous or rather phoſphoreal ſmell with which violent electricity is always attended, and other ſenſible qualities, are aſcribed to the groſſer particles of bodies driven from them by the forcible action of this ether. He alſo endeavours to explain many electrical phenomena by means of a ſubtile medium at the ſurface of all bodies; which is the cauſe of the refraction and reflection of the rays of light, and alſo reſiſts the entrance and exit of this ether. This medium, he ſays, extends to a ſmall diſtance from the body, and is of the ſame nature with what is called the *electric fluid*. On the ſurface of conductors this medium is rare, and eaſily admits the paſſage of the electric fluid; whereas, on the ſurface of electrics, it is denſe and reſiſts it. The ſame medium is rarefied by heat, which thus changes conductors into non-conductors. By far the greater number of philoſophers, however, rejected the opinion of Mr Wilſon; and as they neither choſe to allow the electric fluid to be *fire* nor *ether*, they were obliged to own that it was a fluid *ſui generis*, i. e. one of whoſe nature they were totally ignorant.

Sect. II. *Of the Theory of Poſitive and Negative Electricity.*

387 Dr Franklin's theory.

According to this theory, all the operations of electricity depend upon one fluid *ſui generis*, extremely ſubtile and elaſtic. Between the particles of this fluid there ſubſiſts a very ſtrong repulſion with regard to each other, and as ſtrong an attraction with regard to other matter. Thus, according to Dr Franklin's hypotheſis, one quantity of electric matter will repel another quantity of the ſame, but will attract and be attracted by any terreſtrial matter that happens to be near it. The pores of all bodies are ſuppoſed to be full of this ſubtile fluid; and when its equilibrium is not diſturbed, that is, when there is in any body neither more nor leſs than its natural ſhare, or than that quantity which it is capable of retaining by its own attraction, the fluid does not manifeſt itſelf to our ſenſes. The action of the rubber upon an electric diſturbs this equilibrium, occaſioning a deficiency of the fluid in one place, and a redundancy of it in another. This equilibrium being forcibly diſturbed, the mutual repulſion of the particles of the fluid is neceſſarily exerted to reſtore it. If two bodies be both of them overcharged, the electric atmoſpheres repel each other, and both the bodies recede from one another to places where the fluid is leſs denſe. For as there is ſuppoſed to be a mutual attraction between all bodies and the electric fluid, ſuch bodies as are electrified muſt go along with their atmoſpheres. If both the bodies are exhauſted of their natural ſhare of this fluid, they are both attracted by the denſer fluid exiſting either in the atmoſphere contiguous to them, or in other neighbouring bodies; which occaſions them ſtill to recede from one another as if they were overcharged.

288 Difficulty concerning the reaſon why bodies negatively electrified repel one another.

This is the Franklinian doctrine concerning the cauſe of electric attraction and repulſion; but it is evident, that the reaſon juſt now given why bodies negatively attracted ought to repel one another, is by no means ſatisfactory. Dr Franklin himſelf had framed his hypotheſis before he knew that bodies negatively electrified would repel one another; and when he came afterwards to learn it, he was ſurpriſed, and acknowledged that he could not ſatisfactorily account for it *.

289 Different ſolutions of this difficulty.

Other philoſophers therefore invented different ſolutions of this difficulty, of which that above mentioned is one. But by ſome this was rejected. They ſaid, that as the denſer electric fluid, ſurrounding two bodies negatively electrified, acts equally on all ſides of thoſe bodies, it cannot occaſion their repulſion. The repulſion, according to them, is owing rather to an accumulation of the electric on the ſurfaces of the two bodies; which accumulation is produced by the attraction, and the difficulty the fluid finds in entering them. This difficulty is ſuppoſed chiefly to be owing to the air on the ſurface of bodies, which Dr Prieſtley ſays is probably a little condenſed there. This he deduces from an experiment of Mr Wilſon, corrected by Mr Canton. The experiment was made in order to obſerve the courſe of the electric light through a Torricellian vacuum. A ſingular appearance of light was obſerved upon the ſurface of the quickſilver, at which the fluid was ſuppoſed to enter. Mr Wilſon ſuppoſed that this was owing to a ſubtile medium ſpread over the ſurface of the quickſilver, and which prevented the eaſy entrance of the electric fluid. But this was afterwards diſcovered by Mr Canton to be owing to a ſmall quantity of air which had been left in the tube. It is plain, however, that as the attraction is equal all round, and likewiſe the difficulty with which the fluid penetrates the air, bodies negatively electrified ought not to repel one another on this ſuppoſition more than the former. Nay, they ought to attract each other; becauſe, in the place of contact, the reſiſtance of the air would be taken off, and the electric fluid could come from all other quarters by the attraction of the bodies.

290 Inſufficient.

This theory is evidently no ſolution of the difficulty; ſeeing it is only explaining one fact by another, which requires explanation at leaſt as much as the firſt. We ſhall ſee hereafter how this difficulty may be explained.

291 Dr Franklin's explanation of the phenomena of the Leyden phial.

What gave the greateſt reputation to Dr Franklin's theory, was the eaſy ſolution which it afforded of the phenomena of the Leyden phial. The fluid is ſuppoſed to move with the greateſt eaſe in bodies which are conductors, but with extreme difficulty in *electrics per ſe;* inſomuch that glaſs is abſolutely impermeable to it. It is moreover ſuppoſed, that all electrics, and particularly glaſs, on account of the ſmallneſs of their pores, do at all times contain an exceeding great, and always an equal quantity of this fluid; ſo that no more can be thrown into any one part of any electric ſubſtance, except the ſame quantity go out at another, and the gain be exactly equal to the loſs. Theſe things being previouſly ſuppoſed, the phenomena of charging and diſcharging a plate of glaſs admit of an eaſy ſolution. In the uſual manner of electrifying by a ſmooth glaſs globe, all the electric matter is ſupplied by the rubber from all the bodies which communicate with it. If it be made to communicate with nothing but one of the coatings of a plate of glaſs, while the conductor communicates with the other, that ſide of the glaſs which communicates with the rubber muſt neceſſarily be exhauſted in order to ſupply the conductor, which muſt convey the whole of it to the ſide with which it communicates. By this operation, therefore, the electric fluid becomes almoſt entirely exhauſted on one ſide of the plate, while it is as much accumulated on the other; and the diſcharge is made by the electric fluid ruſhing, as ſoon as an opportunity is given it by means of proper conductors, from the ſide which was overloaded to that which is exhauſted.

It is not, however, neceſſary to this theory, that the very ſame individual particles of electric matter which were thrown upon one ſide of the plate, ſhould make the whole circuit of the intervening conductors, eſpecially in very great diſtances, ſo as actually to arrive at the exhauſted ſide. It may be ſufficient to ſuppoſe, that the additional quantity of fluid diſplaces and occupies the ſpace of an equal portion of the natural quantity of fluid belonging to thoſe conductors in the circuit which lay contiguous to the charged ſide of the glaſs. This diſplaced fluid may drive forwards an equal quantity of the ſame matter in the next conductor; and thus the progreſs may continue till the exhauſted ſide of the glaſs is ſupplied by the fluid naturally

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* *Franklin's Letters.*

rally exiſting in the conductors contiguous to it. In this caſe, the motion of the electric fluid, in an exploſion, will rather reſemble the vibration of the air in ſounds, than a current of it in winds.

It will ſoon be acknowledged (ſays Dr Prieſtley), that while the ſubſtance of the glaſs is ſuppoſed to contain as much as it can poſſibly hold of the electric fluid, no part of it can be forced into one of the ſides, without obliging an equal quantity to quit the other ſide: but it may be thought a difficulty upon this hypotheſis, that one of the ſides of a glaſs plate cannot be exhauſted, without the other receiving more than its natural ſhare; particularly, as the particles of this fluid are ſuppoſed to be repulſive of one another. But it muſt be conſidered, that the attraction of the glaſs is ſufficient to retain even the large quantity of electric fluid which is natural to it, againſt all attempts to withdraw it, unleſs that eager attraction can be ſatisfied by the admiſſion of an equal quantity from ſome other quarter. When this opportunity of a ſupply is given, by connecting one of the coatings with the rubber, and the other with the conductor, the two attempts to introduce more of the fluids into one of the ſides are made, in a manner, at the ſame inſtant. The action of the rubber tends to diſturb the equilibrium of the fluid in the glaſs; and no ſooner has a ſpark quitted one of the ſides, to go to the rubber, than it is ſupplied by the conductor on the other; and the difficulty with which theſe additional particles move in the ſubſtance of the glaſs, effectually prevents its reaching the oppoſite exhauſted ſide. It is not ſaid, however, but that either ſide of the glaſs may give or receive a ſmall quantity of the electric fluid, without altering the quantity of the oppoſite ſide. It is only a very conſiderable part of the charge that is meant, when one ſide is ſaid to be filled while the other is exhauſted.

It is a little remarkable, adds Dr Prieſtley, that the electric fluid, in this and in every other hypotheſis, ſhould ſo much reſemble the ether of Sir Iſaac Newton in ſome reſpects, and yet differ from it ſo eſſentially in others. The electric fluid is ſuppoſed to be, like ether, extremely ſubtile and elaſtic, that is, repulſive of itſelf; but inſtead of being, like the ether, repelled by all other matter, it is ſtrongly attracted by it: ſo that, far from being, like the ether, rarer in the ſmall than in the large pores of bodies, rarer within the bodies than at their ſurfaces, and rarer at their ſurfaces than at any diſtance from them; it muſt be denſer in ſmall than in large pores, denſer within the ſubſtance of bodies than at their ſurfaces, and denſer at their ſurfaces than at a diſtance from them.

292
Attraction and repulſion through glaſs accounted for.

To account for the attraction of light bodies, and other electrical appearances, in air of the ſame denſity with the common atmoſphere, when glaſs (which is ſuppoſed to be impermeable to electricity) is interpoſed; it is conceived, that the addition or ſubtraction of the electric fluid, by the action of the excited electric on one ſide of the glaſs, occaſions, as in the experiment of the Leyden phial, a ſubtraction or addition of the fluid on the oppoſite ſide. The ſtate of the fluid, therefore, on the oppoſite ſide being altered, all light bodies within the ſphere of its action muſt be affected in the very ſame manner as if the effluvia of the excited electric had actually penetrated the glaſs, according to the opinions of all electricians before Dr Franklin.

293
Improvement of Franklin's theory by Æpinus and Cavendiſh.

This hypotheſis has been greatly improved by M. Æpinus of St Peterſburgh, and by the Hon. Henry Cavendiſh; and we ſhall now proceed to an illuſtration of the theory as given by theſe gentlemen.

Theory of Æpinus.

294
Hypotheſis of Æpinus.

Electrical phenomena are produced by a fluid of a peculiar nature, which we call the ELECTRIC FLUID; which has the following properties.

1. Its particles repel each other with a force increaſing as the diſtances decreaſe.

295 2. Its particles attract the particles of all other matter with a force increaſing as the diſtances decreaſe, and this attraction is mutual.

296 3. The ELECTRIC FLUID by reaſon of its extreme ſubtility is capable of penetrating other bodies, but all bodies are not penetrated by it with equal facility. In thoſe bodies which we call *non-electrics*, ſuch as metals and water, it moves very readily; but in thoſe bodies which have been called *electrics per ſe*, ſuch as glaſs, &c. it either does not move at all, or moves with great difficulty.

297 4. Every body has a certain quantity of *electric fluid* which is proper to it, and may therefore be called its *natural quantity*: this quantity is proportional to the maſs.

5. We ſay that a body is electrified *poſitively* when the quantity of electric fluid which it has in any way received is greater than its *natural quantity*; and when that quantity is leſs than its natural quantity, we ſay that the body is electrified *negatively*.

298 6. The phenomena which depend on the action of the *electric fluid* may be reduced to two claſſes; the firſt comprehending the caſes in which the fluid removes from one body into another which has leſs of it; the other thoſe in which the bodies containing the fluid are in motion, ſo as to approach or recede from each other, or ſo as to attract and repel each other.

Such is the hypotheſis of M. Æpinus; let us now inquire what conſequences may be drawn from it.

299 Let us ſuppoſe a body to contain a certain quantity of the electric fluid, and let us examine the ſtate of a particle of the fluid, as P, near the ſurface of the body. There is a mutual attraction between the particle P, and the particles of matter in the body; and there is a mutual repulſion between it and the other particles of electric fluid in the body. The whole attracting force may be *equal* or *unequal* to the whole repulſive force. If they be equal, P is in equilibrio, and has no tendency to motion.

Now let us ſuppoſe the body to have received a quantity of fluid over and above its natural quantity; i. e. let the body be electrified *poſitively*. As, while the body was in its natural ſtate, the attractive and repulſive forces were in equilibrio, the increaſe of fluid will augment the repulſive force, which will now exceed the attractive force, and the particle P will be repelled towards that ſurface to which it is neareſt, till it at length quits the body. The repulſive power will continue to act upon other particles, which will be ſucceſſively puſhed nearer the ſurface, ſo as to produce a conſtant *efflux* of the fluid till the equilibrium is re-eſtabliſhed, ed, or till the body contains no more than its natural quantity.

300 Let us now conceive that the body has loſt a quantity of electric fluid, or that it is electrified *negatively*. The repulſive force of the fluid upon the particle P will then be leſs than the attractive force of the matter contained in the body or the ſame particle, this attraction will begin to act, and the particle will move nearer the centre. The attraction continuing to act, particles near the ſurface, and thoſe of contiguous bodies will ſucceſſively move towards the centre of the body; or a continual *influx* of fluid will take place till the equilibrium is reſtored.

301 Saturation defined. DEFINITION.—When a body contains its natural quantity of electric fluid, we ſhall ſay that it is *ſaturated*.

302 It will be convenient for us to have general expreſſions for theſe ſeveral ſtates of a body, in order the better to eſtimate the forces.

Let Q repreſent the natural quantity of fluid,
a, the attractive force of the other matter in the body, which we ſhall hereafter call ſimply the *matter*,
r, the repulſive force of the fluid; and
f, the redundant or deficient fluid.

Then in the caſe in which a body is *ſaturated*, $a-r$ will repreſent the degree of force with which the particle P is attracted; and $r-a$ the force with which it is repelled. But here $a=r$; conſequently $a-r$ and $r-a=o$.

But let the quantity *f* be added to Q, and uniformly diſtributed through the body; the fluid will now be $Q+f$. As we muſt admit the repulſive force to be proportional to the quantity of fluid, we ſhall have $Q : Q+f = r : \frac{(Q+f)\times r}{Q}$, or $\frac{Qr}{Q}+\frac{fr}{Q}$, or $r+\frac{fr}{Q}$. This quantity will repreſent the force with which P is repelled by the whole fluid of the body. But it is alſo attracted by the matter of the body, with the force *a*; the whole force exerted on P will therefore be $a-r-\frac{fr}{Q}$; but $a-r=o$: the whole action exerted on P is therefore $\frac{fr}{Q}$, or the force with which the particle P is repelled, is $\frac{fr}{Q}$.

303 To conceive this more readily, we are to remember that when the quantity of fluid $=Q$, P is in equilibrio; it will therefore be neceſſary only to conſider the action of the ſuperabundant fluid *f*. Then to find the repulſive force of this, we ſay $Q : f = r : \frac{fr}{Q}$ as before; but to this we muſt affix the ſign —, as we muſt conſider repulſive forces as *negative*, and attractive as *poſitive*. The particle P then being repelled with this force $\frac{fr}{Q}$, it will quit the body unleſs it be oppoſed by ſome obſtacle, and the repelling force continuing to act on other particles, an *efflux* of fluid will be produced. The force $\frac{fr}{Q}$ will however be continually diminiſhing, but will not entirely ceaſe till $f=o$.

304 Now let the quantity of fluid *f* be ſubtracted from Q. Then $\frac{(Q-f)\times r}{Q} = r-\frac{fr}{Q}$ will repreſent the force with which P is repelled. But it is attracted with the force *a*; the whole action therefore exerted on P is $a-r+\frac{fr}{Q}$: but $a-r=o$; therefore the whole force $=\frac{fr}{Q}$, which repreſents the force with which P is attracted.

When there is a deficiency of fluid there is a proportional redundancy of matter, and *vice verſa*. Hence we may deduce the following inference.

305 Electrical phenomena depend on a redundancy of fluid or of matter. *The production of electrical phenomena depends entirely on a redundancy of fluid or a redundancy of matter.*

306 Cauſes obſtructing theſe effects. There are two cauſes which obſtruct or prevent the effects which we have been deſcribing; the one depending on the nature of the body itſelf, the other on that of the ſurrounding bodies. The firſt cauſe of obſtruction takes place when the bodies themſelves are thoſe which are called *electrics per ſe*, in which the fluid moving with conſiderable difficulty, its *efflux* in the firſt caſe, and its *influx* in the ſecond, will be alike retarded. The ſecond cauſe acts when the ſurrounding bodies are *electrics per ſe*, as *very dry air*; as the reſiſtance which theſe oppoſe to the motion of the fluid, will produce in the *efflux* or the *influx*, a retardation ſimilar to that which ariſes from the electric nature of the electrified body. We may hence conclude that a body will continue to exhibit electrical phenomena for a longer time, *cæteris paribus*, according as the body itſelf, or the bodies by which it is ſurrounded, approach neareſt to the nature of *electrics per ſe*, whence we ſee how electrics are uſeful in confining the electric fluid, or in *inſulating* electrified bodies.

307 Illuſtration. The conductors of an electric machine will afford a familiar illuſtration of the above principles as far they relate to *non-electrics*. In the ordinary machine, in which a cylinder is employed, the cuſhion and ſilk by which the cylinder is rubbed communicate to it a portion of the fluid which they contain, the loſs of which they ſupply from the neighbouring bodies with which they communicate, when the chain connects the rubber with the earth, &c. The fluid is then communicated from the cylinder to the prime conductor by the points placed on the ſide of it, and the conductor becomes electrified poſitively. The glaſs pillar by which the conductor is ſupported, and which is an *electric per ſe*, oppoſes the farther propagation of the fluid, and prevents its eſcape on one ſide, while the ſurrounding air, if it be very dry, oppoſes its eſcape on the other; ſo that the conductor will retain for a moment the exceſs of fluid which it has received. Now, if we preſent a fine metallic point to the prime conductor, a ſmall luminous ſtar will appear at the point; indicating, as we have before ſeen, a poſitive electricity. This ſtar is produced by the *efflux* of the electric fluid from the conductor, the particles of the fluid being impelled by their mutual repulſion, and by the attraction of the point to approach and penetrate this, as we ſhall more fully ſee hereafter.

When the rubber is inſulated, as it is perpetually communicating a portion of its fluid to the cylinder, without being able to procure a freſh ſupply from the ſurrounding bodies, it is continually acquiring a negative electricity. There will now be a continual *efflux* of fluid from the conductor towards the cuſhion, and the conductor will, in its turn, be electrified negatively. In this caſe, if we preſent a fine metallic point to the conductor, there will iſſue from the point a luminous pencil, which is produced by the *efflux* of fluid from the point to the conductor, in order to reſtore the equilibrium.

308 Effect of an unequal diſtribution of fluid.

We have hitherto conſidered the fluid as uniformly diffuſed through the body. But it will often happen, that there will be a redundancy of fluid in one part of the body, while there is at the ſame time a deficiency in another part. In order to ſimplify our formula, we ſhall ſuppoſe the body BC (fig. 96.) divided into two equal parts, AB, AC, and that the fluid in AB exceeds its natural quantity, while that in AC is leſs than the ſame quantity, the proportion of the fluid acquired on one ſide to that loſt on the other being variable at pleaſure. Let us examine the ſituation of two particles P, p, placed towards the two extremities.

Plate CXCIII.

Let Q repreſent the quantity of fluid neceſſary for the ſaturation of AB or AC,
a = the attraction of the whole matter in AB for the particle P or p,
r = the repulſion of the whole fluid uniformly diſtributed in AB on the ſame particle,
r' = the repulſion of an *equal quantity* of fluid in AC on the ſame particle,
f = the quantity of redundant fluid in AB,
and g = the deficient quantity in AC.

309 Action on external fluid.

Now the force by which the particle P or p is attracted by the matter of BC when *ſaturated*, will be $a-r-r'$, which when the body is in its natural ſtate will be equal to o. But AB contains the redundant fluid f, and AC the deficient fluid g. The whole action exerted muſt therefore be $a-\frac{(Q+f)\times r}{Q}-\frac{(Q-g)\times r'}{Q}$. But $a-r-r'=o$; therefore the whole action is $\frac{gr'-fr}{Q}$, or rather, ſince r is greater than r', $\frac{fr-gr'}{Q}$, which will repreſent the force by which the particle P is repelled. In the ſame manner, $\frac{gr-fr'}{Q}$ will repreſent the force by which p is attracted.

310 Action on internal fluid.

Now, let us ſuppoſe a particle p' in the middle of the body BC; while the body is ſaturated, it will be in equilibrio; but as the one half of the body AB contains the redundant fluid f, and the half AC the deficient fluid g, the particle p' will be repelled in the direction AC by the force $\frac{fr}{Q}$. But it is repelled in the direction AB by the force $\frac{gr}{Q}$; therefore the whole repulſive force by which it is impelled in the direction AC will be $\frac{fr+gr}{Q}$, or $\frac{\overline{f+g}\times r}{Q}$.

311 An uniform diffuſion will be produced if there be no obſtruction.

From what we have ſaid above, it appears that ſo long as there is a redundancy of fluid in AB, and a deficiency in AC, the redundant fluid has a tendency to flow from A to C; and if the body be a perfect conductor, or ſuch as is permeable to the fluid, its ſtate cannot be permanent till the fluid is uniformly diſtributed between the two halves, unleſs it is acted on by ſome external force. But in a non-conductor, or perfect electric, this ſtate may ſubſiſt, and it will be continued for a longer or a ſhorter time, in proportion as the electric be more or leſs perfect.

If we had ſuppoſed the part AC to be overcharged, inſtead of AB, P would have been repelled with a ſtronger force, which would be repreſented by $\frac{f\times\overline{r+r'}}{Q}$, which is evidently greater than $\frac{fr-gr}{Q}$, the repulſive force in the firſt caſe. The particle p is alſo leſs attracted than before, when AB is undercharged inſtead of AC.

The above remarks will equally apply to the caſe of two conducting bodies AB and CD, fig. 98. ſeparated by an electric, Z. 312

It is proper to obſerve that the quantities f and g, were indefinite in the above reaſoning. Their value may be ſuch that the tendency to influx or efflux may ceaſe, or may be reverſed; for ſuppoſing $gr'-fr=o$, or $g:f=r:r'$; and we ſhall have $g=\frac{fr}{r'}$. In this caſe the attraction of the redundant matter balances the repulſion of the redundant fluid, and P is neither attracted nor repelled. Hence we have this important fact, that *a body may be neutral, even where it is redundant or deficient.* 313

When one extremity of the body is thus rendered inactive, the ſtate of the other extremity is changed. To find this ſtate we muſt put $\frac{fr}{r'}$, in place of its equal g, in the formula $\frac{gr-fr'}{Q}$; and we ſhall have $f\times\left(\frac{r^2-r'^2}{Qr}\right)$.

Again the forces may be ſo balanced, that there ſhall be no tendency to influx at C, fig. 96. Make $g=\frac{fr}{r'}$, which expreſſes the action at C. The action at B, the other end, will be obtained by putting $\frac{fr}{r'}$, in place of g in the formula $\frac{fr-gr'}{Q}$ as before, and the reſult $f\times\left(\frac{r'^2-r^2}{Qr}\right)$, will expreſs the repelling force at B. 314

In order, the better to conceive the relative effects in each of the above caſes, we muſt obſerve that the repulſion of the part AB on the particle P muſt increaſe in proportion as the quantity of additional fluid acquired by AB is greater. On the other hand the attraction of the part AC for the ſame particle will increaſe according as the quantity of fluid ſubtracted from AC is greater. Now, as we have ſuppoſed the quantities of fluid in the two parts variable, we may ſuppoſe a caſe to happen, in which, for inſtance, the quantity loſt by AC may be ſuch that the exceſs of its attraction on P thence reſulting, may exactly counterbalance the diminiſhed attraction ariſing from its great diſtance, compared to the repulſion of the part AB on the ſame

ſame particle. In this caſe, P will remain immoveable.

If, on the contrary, the quantity of fluid loſt by AC be not ſufficient to compenſate for the greater diſtance, the repulſion of AB will prevail over the attraction of AC, and the particle P will quit the body.

The particle *p* will alſo undergo certain changes in theſe different caſes. If the particle P remain immoveable, for inſtance, the particle *p* will have a progreſſive motion towards the body A, ſince this is near the part AC of which the attractive force in this caſe exceeds the repulſive force of AB. If the particle P has already a tendency towards the body A, the particle *p* will for a ſtill ſtronger reaſon be attracted towards A.

In general, according to the different degrees of force exerted by the two parts of the body, it will happen that the fluid will be attracted and repelled on both ſides by turns, or it will be attracted on one ſide, while it is repelled on the other, and *v. v.* or laſtly, it may remain immoveable on one ſide, while it is attracted or repelled on the other.

315 If we ſuppoſe that the redundancy of fluid in AB is exactly equal to the deficiency in AC, then the particle *p* will have a tendency to penetrate the body A, while the particle P will be repelled by it.

To prove this, let us ſuppoſe that the parts AB, AC act by turns on the particle *p* placed at a determinate diſtance; and let us conceive the repulſive force of the part AB to be concentrated in a determinate point, while the attractive force of the part AC muſt be ſuppoſed concentrated in a correſponding point on the other ſide. For, whatever be the law, in proportion to the diſtance which the repulſion of the particles of the electric fluid follows; the attraction of the particles of matter in the electrified body ought to follow the ſame law: ſince, without this, there could be no counterpoiſe between the attraction and repulſion of the particles in the natural ſtate of the body. It follows then, that the attraction exerted by AC upon the particle *p* muſt be equal, in the preſent caſe, to the repulſion of AB on the ſame particle. Since, on one ſide, the particle is repelled by AB by reaſon of the exceſs of fluid in that part, and on the other it is attracted by AC by reaſon of the quantity of matter in that part, and which is proportional to the quantity of fluid which is ſuppoſed to have paſſed into AB. In the preſent caſe, therefore, where the particle *p* is nearer to AC than to AB, the attraction will prevail over the repulſion, and the particle will penetrate to AB, and paſs through it to the body A.

In the ſame manner we might prove that the particle P would be repelled from A.

316 The equilibrium between the forces of the parts AB, AC being diſturbed, it is clear that there will be an attempt to reſtore it, ſo that a portion of the redundant fluid in AB will paſs into AC, till the body be brought back to its natural ſtate. The return to this ſtate will be more or leſs ſlow, according as the body is a more or leſs perfect electric; but if it is a conductor the fluid will pervade it in an inſtant, and an equal diſtribution will immediately take place.

317 Nature of the obſtructions conſidered.

It has been ſtated that the fluid does not move with equal facility through all bodies, but that in moving through electrics it meets with more or leſs reſiſtance. It will be proper, before we proceed farther, to conſider the nature of this reſiſtance. It may either ariſe ſolely from the inertia of the particles of the fluid, which is the caſe in a perfect fluid; or it may reſemble the reſiſtance oppoſed by a parcel of grain to the deſcent of ſmall ſhot through it, or the reſiſtance of a plaſtic or ductile body, ſuch as clay or lead, to the motion of a body through its pores. In the firſt caſe, any inequality of force, however ſmall, is capable of producing a uniform diſtribution of the fluid, or at leaſt ſuch a diſtribution as will make the exceſs of the mutual attractions and repulſions equal to the degree of external force by which an unequal diſtribution may be kept up. But in the two laſt caſes, before a particle of fluid can change its place, it muſt overcome the tenacity of the adjoining particles of the body, and, conſequently, when an unequal diſtribution has been produced by an external force, it will not be rendered equable by a removal or alteration of that force, but there will remain ſuch an inequality of diſtribution, as will cauſe the want of equilibrium between the attractions and repulſions to be counterbalanced by the tenacity of the body.

From the different ſtates of the particles P, *p*, as deſcribed in the above caſes, we may conclude, that, during the return of a body to its natural ſtate, the readineſs with which the fluid flows from AB into AC muſt depend much on the nature of the ſurrounding bodies, and the greater or leſs facility with which theſe are pervaded by the electric fluid.

318 If the fluid is not uniformly diſtributed throughout every part of the body, or if, though there be a uniform diſtribution, the two parts of the body are unequal, we ſhall always obtain reſults analogous to thoſe which have been given. There is an infinity of caſes ſuppoſable, relative to the different ſtates of AB and AC; but as each of theſe caſes has a determinate relation to the moſt ſimple caſe, which we have been conſidering, it may always be reduced to this.

Let us ſuppoſe, for example, that the part AB is double, triple, &c. the part AC, and that the portion of fluid, which is ſuperabundant in AB, is equal to that which is deficient in AC: If we conceive the particle *p* ſituated between theſe two parts, the point in which we muſt ſuppoſe the repulſive force of AB to be concentrated, will not be the ſame as that given in (315); but the point in which *p* muſt be placed that it may be attracted by AC and repelled by AB, will be between the centres of action of AB and AC, though not at an equal diſtance from theſe parts. Then, in the caſe where *p* is nearer to the centre of action of AC than to that of AB, this particle will tend to penetrate into AC, while the particle P will be equally repelled from it.

319 Actions of electrical bodies on each other.

Having thus examined the action between the particles of fluid moving in a body, and the particles of matter in the ſame body, we ſhall proceed to conſider the action of electrified bodies on each other.

Let there be two bodies, A and B, in their natural ſtate.

Let M repreſent the common matter in A.
m, the common matter in B.
F, the fluid required to ſaturate A.
f, the fluid required to ſaturate B.
z, the mutual action between a particle of fluid and the correſpondent matter. This action is repreſent-

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ed by an unknown quantity, becauſe it is indeterminate: varying with every change of diſtance.

As the actions of theſe bodies on each other are reciprocal, it will be ſufficient here to conſider how the body A is affected. There are three circumſtances to be taken into conſideration.

1. The particles of fluid in A attract the particles of matter in B with the force z; ſo that the whole attraction of A on B will be the product of F and m multiplied by z or Fmz; or

1ſt. F tends towards m with the force $+Fmz$.

2. The particles of fluid in A repel the particles of fluid in B with the ſame force z; ſo that the whole repulſion of A on B will be Ffz; or

2d. F tends to ſeparate from f with the force $-Ffz$.

3. The particles of matter in A are attracted by the particles of fluid in B with the ſame force z, ſo that the whole attraction of B on A will be Mfz; or,

3d. M tends to approach f with the force $+Mfz$.

The whole tendency of A to approach or to ſeparate from B may therefore be repreſented by the ſymbol $z\times\overline{Fm+Mf-Ff}$. But as, from the hypotheſis, the attraction of the particles of fluid in A for the particles of matter in B is equal to the repulſion between the particles of fluid in A and the particles of fluid in B, which are competent to the matter attracted by the fluid in A, the attraction Fmz is balanced by the repulſion Ffz. We have, therefore, only to conſider the remaining attraction, or the attraction of the matter in A for the fluid in B, or Mfz. On the whole, therefore, A will move towards B, and, as all action is equal and contrary, B will move towards A with an equal force.

320 Deficiency in the hypotheſis ſupplied.

This would be the neceſſary conſequence of the hypotheſis, as it ſtands; but as we ſee no attraction between bodies in their natural ſtate, there muſt be ſome defect in the hypotheſis. To remedy this, Æpinus brings another repulſive force into play, and ſuppoſes that every particle of matter in A repels every particle of matter in B, as much as it is attracted by ſo much of the fluid in B as is neceſſary for its ſaturation. Now, therefore, the whole action exerted by B on A will be $z\times\overline{Fm-Ff-Mm+Mf}$, ſo that as Fmz is balanced by Ffz, and Mmz by Mfz, there will remain no exceſs on either ſide, and conſequently the bodies will have no tendency to motion.

321 Æpinus defended.

Great objection has been made to this additional part of M. Æpinus's hypotheſis, and indeed Æpinus himſelf acknowledges, that this circumſtance appeared to him hardly admiſſible; it ſeeming inconceivable that a particle in A ſhall repel a particle in B, or recede from it electrically, while it tends toward it by planetary gravitation. But more attentive conſideration ſhewed him, that there was nothing in it contrary to the obſerved analogy of natural operations. 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 it difficult to reconcile this repulſion with univerſal gravitation; for while bodies are in their natural ſtate, the electric attractions and repulſions balance each other, and there is nothing to diſturb the phenomena of planetary gravitation; and when they 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, nothing is more certain than that bodies exhibit at once the appearances which we endeavour to expreſs by theſe words. We bring the north poles of two magnets near each other, and they recede from each other; 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 ſo 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 one but not the other, &c. We do not underſtand, nor can we conceive, how either force, or how gravity reſides in a body. 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.

In order to ſimplify the algebraic expreſſions which we employ in conſidering the actions of theſe bodies, we may remark, that, as in the natural ſtate of the bodies they do not affect each other, we need only, in examining the actions of bodies not in their natural ſtate, conſider the action of the redundant fluid or the redundant matter in them, that is, the fluid or matter which is *unſaturated*: for we may conſider an *overcharged* body as one which contains a quantity of *ſaturated* fluid, and a quantity of *unſaturated* fluid additional; and an *undercharged* body as one containing a quantity of *ſaturated matter*, and a quantity of *unſaturated matter* in addition. 322

Suppoſe two bodies A and B overcharged, or containing each a quantity of unſaturated fluid, which we ſhall call F' and f'. Their mutual action on each other will be $F'\times f'+z$, and it is evident from what was ſaid before that this is a repulſion. Hence we have the following general propoſition.

1. *Two overcharged bodies repel each other with the force* $F'\times f'+z$. 323

Now let theſe bodies be *undercharged*, or contain each a quantity of unſaturated matter, M', m'. Their mutual action will now be $M'\times m'+z$. This action is alſo repulſive, and hence

2. *Two undercharged bodies repel each other with the force* $M'\times m'+z$. 324

Again, let one of the bodies A be *overcharged* or contain the *unſaturated fluid* F', and the other B *undercharged*, or contain the *unſaturated matter* m'. Their mutual action will now be expreſſed by the ſymbol $F'\times m'+z$, and will be attractive; or

3. *Two bodies which are*, one overcharged, *and* the other undercharged, *attract each other with the force* $F'\times m'+z$. 325

Laſtly, let one of the bodies be overcharged or undercharged, and the other in its natural ſtate. We infer from the above formulæ, that they will neither attract nor repel each other, or that they will be *neutral;* for here either F' or f', or M' or m', one of the factors which made part of the above products, is wanting. This may be inferred alſo, independently of the formulæ, by conſidering

ſidering that the redundant fluid or redundant matter in one body, is as much repelled or attracted by the fluid or matter in the other, as it is attracted or repelled by the matter or fluid in this other. Hence.

326 4. *If of two bodies, one be in its natural ſtate, they will neither attract nor repel each other.*

327 The truth of the three firſt propoſitions will be evident from the experiments related in the laſt Part, Chap. I. where we found that bodies which were electrified *both poſitively* or *both negatively*, repelled each other, and that when one body was electrified *poſitively* and the other *negatively*, they attracted each other. But the laſt propoſition ſeems contrary to the phenomena; and it certainly contradicts a part of the Franklinian doctrine, which maintains that there is an attraction between an *electrified* and a *non-electrified* body, we ſhall preſently, however, demonſtrate the truth of the propoſition, but muſt now proceed in our explanation of Æpinus's theory.

328 Suppoſe the body BC, fig. 97. to be overcharged in the half AC, and undercharged in the half AB, and let us now repreſent the redundant fluid in the part AC by the ſymbol f', and the redundant matter in AB by m'; let the body D near BC be overcharged with the redundant fluid F'; let z and z' denote the force of action exerted on D at the diſtances of this body from the overcharged or undercharged parts of BC. Now D is repelled by AC, with the force $F' f' z'$, but it is attracted by AB with the force $F' m' z'$; on the whole, therefore, D will be attracted or repelled by BC, according as $F' m' z$ is greater or leſs than $F' f' z'$, or (becauſe F is common to both) as $m' z'$ is greater or leſs than $f' z$. But this will depend on the proportion that f' bears to m', or z to z'. Now, the former of theſe is regulated by many external circumſtances which may tend to produce a greater or leſs redundancy or deficiency of fluid; and the latter depends on the *law* of electric action. Without inquiring at preſent into this law, it is ſufficient to recollect that the action *decreaſes* with every *increaſe* of diſtance, and that the attraction and repulſion at the ſame diſtance are *equal*. Both, therefore, vary according to the ſame law, and z is always greater than z'.

But the ſenſible action of BC on D, and (as action and reaction are equal and contrary) of D on BC, may vary with every new poſition of BC, and even in the ſame poſition.

329 1. Let us ſuppoſe that BC contains on the whole its natural quantity of fluid, but that part of it is taken from AB, and crowded into AC. This, which is a very common caſe in electricity, may be expreſſed in our ſymbolic manner by making $f' = m'$. Now, in this caſe, $F' f' z$ is greater than $F' m' z'$, as z is greater than z'. A mutual repulſion will therefore take place between BC and D, and this may be expreſſed by $F' f' \times (z - z')$.

330 2. If D were placed on the redundant ſide of BC, it is evident that the action would be reverſed, and the above ſymbol will expreſs the *attraction* between BC and D.

Again, if inſtead of ſuppoſing D to be *overcharged*, we make it undercharged, the actions will again be changed: in its preſent ſituation it will be repelled; on the oppoſite ſide of BC it will be attracted.

331 3. No action may be exerted between them; for the redundancy and deficiency in BC may be inverſely proportional to the forces, or we may have $f'\, m' : = z' : z$. Now, multiplying extreme and mean terms, we have $f' z = m' z'$, and again $m' = \frac{f' z}{z'}$. In this caſe the actions counterbalance each other, and when D is at the preſent diſtance from the overcharged part AC, it is neither attracted nor repelled. D, and that part of BC that is contiguous to it, may both be overcharged, and yet BC may exert no action on D, or may be *neutral* with reſpect to it.

332 Now ſuppoſe D on the oppoſite ſide of BC; the effects will be different; for as $m' = \frac{f' z}{z'}$, and $m' z'$ is now become $m' z$, and $f' z$ is changed into $f z'$, the action on D will be expreſſed by $F' \times \left(\frac{f' z}{z'} - f' z'\right) = F' f' \times \frac{z^2 - z'^2}{z'}$; of courſe D will be attracted.

333 Again, we may have f' and m' ſo proportioned as that when D, which we ſuppoſe overcharged, is placed at the undercharged end of BC, it ſhall be neither attracted nor repelled, or that at this exact diſtance BC ſhall be *neutral*. In this caſe, $m' = \frac{f z'}{z}$. But if D be on the oppoſite ſide of BC, it will be ſtrongly repelled with the force $F' f' \times \left(\frac{z^2 - z'^2}{z}\right)$.

334 Bodies neutral at one end have their action at the other increaſed.

Hence we ſee that when the overcharged end of an electrified body becomes *neutral* with reſpect to another body that is alſo overcharged, the undercharged end ſtrongly attracts that body; and when the undercharged end becomes *neutral* to the body, this is ſtrongly repelled by the overcharged end, as we may deduce from this reaſoning the following general concluſion.

When an electrified body is neutral at one end, it is rendered more active at the other.

335 One circumſtance merits particular attention. In the above paragraphs, the neutrality of BC has been confined to a particular diſtance of the body D, it being required that m' ſhould $= \frac{f' z}{z'}$; let D be placed nearer to BC and both z and z' are increaſed. Their increaſe may be in the ſame proportion; or one may increaſe faſter than another: in the former caſe, the value of $\frac{z}{z'}$, remains the ſame, and the neutrality continues; in the latter, if z increaſes faſter than z', $f' z$ becomes greater than $m' z'$, and D will be repelled: on the other hand, if z' increaſes faſter than z, D will be attracted. Let D be carried farther from the overcharged end of BC, and the effects will be reverſed.

336 Effect of unequal diſtribution in both bodies.

We have been ſuppoſing that D is overcharged *throughout*, but let us take two bodies AB, and CD, fig. 98. AB being overcharged in u B, and undercharged in u A; and CD being overcharged in v D, and undercharged in v C.

In the firſt place, let us have the overcharged end of AB oppoſite the undercharged end of CD as in the figure. Let F and f be the fluid natural to each, F' and f' the redundant fluid in u B, and v D, and M' and m' the deficient fluid in u A and v C. Let Z and

Z′ denote the intenſity of action exerted by a particle in u B on a particle in v D and v C; and let z and z' in like manner expreſs the intenſity of action of a particle in u A on a particle in v D and in v C.

It will eaſily appear from the former examples that the action of CD on AB will be

$$\frac{F' m' Z - F' f' Z' - M' m' z + M' f' z'}{F f}$$

; in which formula the attractions are denoted by +, and the repulſions by —.

The attractive or repulſive power will prevail according as the ſum of the firſt and laſt terms in the numerator of the above fraction is greater or leſs than the ſum of the two middle terms. Again the value of each term will vary with the quantity of redundant fluid or of redundant matter, and with the intenſity of the electric action. As it would lead us into too long a diſcuſſion were we to notice the numerous varieties of effect, we ſhall only ſtate the moſt ſimple caſe, as being the moſt frequent and moſt uſeful.

337 Let us ſuppoſe that the overcharged part of each body is as much redundant in fluid as the undercharged part is deficient; in which caſe we have $F' = M'$ and $f' = m'$. The action will now be expreſſed by the formula $\frac{F' f' (Z - Z') - z + z'}{F f}$. It is evident that the external effect produced on AB muſt depend on the law of action; if $Z + z'$ be greater than $Z' + z$, AB will be *attracted*, but if $Z + z'$ be leſs than $Z' + z$, it will be *repelled*.

338 It will be a conſiderable relief to the imagination to expreſs theſe abſtract values by ſome ſenſible quantities, ſuch as lines, and this may conveniently be done in the following manner. From a fixed point in a ſtraight line, meaſure off portions reſpectively equal to BC, BD, AC and AD, between thoſe points of the bodies AB, CD, fig. 98. in which we ſuppoſe the forces of the redundant fluid and matter to be concentrated, and at the extremities of theſe portions erect ordinates proportional to theſe forces. Though the law of action be but imperfectly known, it will readily be ſeen of what kind the movements of the bodies will be. Thus in fig. 100. from C in the line CZ, make $Cp = BC : Cq = BD : Cr = AC$, and $Ct = AD$; and erect the ordinates Pp, Qq, Rr, and Tt. If the action of electricity be like other attractive and repulſive forces with which we are acquainted, that is, decreaſing with an increaſe of diſtance, and more ſlowly as that diſtance becomes greater, the ordinates will be bounded by ſuch a curve as PQRTZ, that will have its convexity towards the axis Cz.

339 In our conſtruction, the pair of ordinates Pp, Qq are evidently equidiſtant with the pair Rr, Tt; as are Pp, Rr, with Qq, Tt. It is alſo clear that the ſum of Pp and Tt is greater than the ſum of Qq and Rr. Biſect Cz in v, and draw Vv perpendicular to it, cutting PT and QR in x and y. Then xv is the half of $Pp + Tt$, and yv is the half of $Qq + Rr$. Again, Qm and Tn being drawn parallel to Cz, it is evident that Pm is greater than Rr, and in general, if any pair of ordinates be brought nearer to C, their difference increaſes; and if two pairs be brought nearer to C, the difference of the nearer pair will increaſe faſter than that of the more remote.

340 To apply what has been ſtated.

1. When the overcharged end of AB is towards the undercharged end of CD, AB is attracted, as $Pp + Tt$ is greater than $Qq + Rr$.

2. The nearer the bodies are brought, the more the attraction will increaſe, as the difference between Pm and Rr is thus made greater.

3. The greater the length of AB or CD, the diſtance BC being the ſame, the more the attraction will increaſe: for pr or qt, (which repreſent the length of AB) being increaſed, Rr is diminiſhed more than Tt.

But if the overcharged end of CD be oppoſite to the overcharged end of AB, their mutual action will be repreſented by $F' f' \left(\frac{-Pp + Qq + Rr - Tt;}{F f}\right)$ and AB will be repelled; the repulſion becoming greater or leſs, as the attractions, by every change of diſtance.

Having thus examined at ſome length the reſults of a redundancy or deficiency of fluid, ſuppoſing it to be immoveable, we muſt now proceed to conſider the conſequences of its mobility.

341 Effect of the mobility of the fluid.

Let D, fig. 97. contain redundant fluid while BC is ſuppoſed in its natural ſtate, and let the fluid in D be fixed, but that in BC moveable. The redundant fluid in D will exert its repulſive power, and will drive the fluid of BC from the proximate end B towards the remote end C, ſo that the fluid will be rarefied in AB, and conſtipated in AC. Without examining here the mutual actions of the redundant fluid and matter, it is clear that we have a caſe ſimilar to that deſcribed in N°309. and as $f' = m'$ and z is greater than z', D will be attracted by BC, with the force $F' f' \times (z - z')$.

We may now ſolve the difficulty mentioned in N° 327. and perceive that the hypotheſis agrees with the fact even in the caſe in which it appeared ſo oppoſite. Had the fluid been immoveable, no attraction would indeed have taken place: but as it is ſuppoſed moveable, the redundant matter in the vicinity of D prevails, and a mutual attraction enſues.

342 For the ſake of greater ſimplicity, we have ſuppoſed the fluid in D immoveable, but let us ſuppoſe it moveable. In that caſe, as ſoon as the uniform diſtribution on BC is diſturbed, and it becomes overcharged in AC, and undercharged in AB, certain forces begin to act on D, tending to diſturb its uniformity. The redundant matter towards B attracts the fluid in D, more than the redundant fluid toward C, which is more remote, repels it; z' being leſs than z. By this attraction the fluid of D tends to be conſtipated in the proximate extremity, and thus again AB is more undercharged, and AC more overcharged than before. Thus the mutual action between the bodies is ſtill more increaſed. But it is ſtill of the ſame kind; for however ſmall the redundancy in D may be, it can never be made deficient in its remote extremity by the irregular diſpoſition of the fluid in BC, unleſs BC contain more or leſs than its natural quantity. By the change in the diſpoſition of fluid in D, it is clear that the ſimilar change in BC muſt be increaſed; the fluid will be ſtill more rarefied at B and condenſed at C, and this will go on till all is *in equilibrio*. There are ſeveral forces combining to hold *in equilibrio* a particle in BC. The redundant fluid in D impels it towards C; but the redundant fluid here again impels it towards B, while the redundant

redundant matter at B attracts it the ſame way; and theſe two forces of BC muſt be ſuppoſed to balance the action of D.

We may here conclude that the denſity of the fluid in BC increaſes gradually from B to C; at B it muſt be leſs, and at C greater than the natural denſity, and there will conſequently be ſome point between B and C where it is of the natural denſity. This point may be called a *neutral* point; though we do not mean to imply by this term that a particle ſituated at this point is neither attracted nor repelled.

343 We have ſuppoſed the fluid in D redundant; but let it be deficient. Then the attraction of the redundant matter in D will change the diſpoſition of the moveable fluid in BC, and will conſtipate it in B, and rarefy it in C. Again, the redundant fluid at B will act more ſtrongly on the moveable fluid in D, and tend to impel it towards the remote extremity; and D will thus become undercharged in its *proximate* extremity, and leſs undercharged at its *remote* end than if BC were away. The unequal diſtribution of fluid in BC will thus be increaſed; but though both BC and D will be farther from their natural ſtate, the remote end of D can never be overcharged.

It is clear, that when things are in the ſtate which we have deſcribed, D and BC will attract each other with the ſame force as when D was equally undercharged.

344 Induced electricity. Let a body, A, (fig. 101.) that is overcharged, be placed near the extremities of two oblong parallel conductors, B and C, that are in their natural ſtate. By the action of A, the fluid in B and C will be repelled towards their remote ends N and *n*, where it will be condenſed, while at their proximate ends, S and *s*, it will be rarefied. Both B will attract and be attracted by A. Now the redundant fluid in NB repels the redundant fluid in *n* C, and in like manner the redundant matter in SB repels the redundant matter in *s* C; the bodies B and C therefore repel each other, and will ſeparate; but they ought to approach each other, for SB attracts *n* C, and NB attracts *s* C; but the repelling parts being nearer each other than the attracting parts, the forces of the former will prevail. If the body A were undercharged, it is clear that the ſame *ſenſible* appearances would take place, though the internal motions of the bodies would be the reverſe of the former.

If another body in the ſame ſtate with A be placed near the oppoſite ends of B and C, their internal motions will be diminiſhed or prevented, and of courſe the ſenſible appearances ſhould diminiſh alſo.

If another conductor, as E, be placed near *s*, oppoſite to A, it will be affected in the ſame manner with C, and its proximate extremity *f* will repel *s*; but if it be placed at the remote end, or in the poſition of F, this remote end will be attracted. As the body A, when redundant or deficient, affects every other body in its vicinity, while theſe do not by themſelves affect each other, A is called the electrified body, and the others are ſaid to be electrified by it. The electricity of theſe bodies is called *Induced Electricity*.

345 Effect of obſtructions. We have hitherto ſuppoſed the fluid moveable, except at firſt in A; but let us ſuppoſe that there is ſome obſtruction to its mobility, and let us examine what will be the conſequences. We may ſtate the obſtruction as uniform, and as being ſuch that ſome ſmall force is required to enable a particle of fluid to paſs between two particles of matter.

When an overcharged body is placed near an imperfect conductor, it is clear that the fluid cannot be propelled to the remote extremity of the conductor in ſo great a quantity. We may conceive the diſtribution of the fluid, by taking a conſtant quantity from the intenſity of the force of the overcharged body at every point of the conductor. This ſhows that the diſtribution will not be ſo unequable between imperfect, as between perfect conductors, and hence that the attraction between the former will not be ſo ſtrong as between the latter. It will alſo be much longer before an *equilibrium* can be brought about. This leads us to an important conſequence; viz. that the neutral point will not be ſo far from the other body when the fluid is of its natural denſity, as it would be, were there no obſtructions. The advance of this point along the imperfect conductor will alſo be very ſlow; and it is clear, that the final accumulation at the remote extremity of an imperfect conductor will be leſs than if the conductor were perfect, and the neutral point will be nearer to the other extremity.

346 The obſtruction we are conſidering will be attended with another remarkable effect. The conſtipation of the fluid at the commencement of the action will always be greateſt at a place much nearer to the diſturbing cauſe than the remote end of the conductor, and beyond that point it will diminiſh. In the time that elapſes during the progreſs of this change, the condenſed fluid tends to repel the fluid beyond it, and thus ſome of this remote fluid may be diſplaced, and a part of the imperfect conductor made deficient, while there is a ſmall condenſation beyond it. By this again a rarefaction and condenſation may be produced in another part, thus cauſing a very irregular diſtribution of the fluid.

The effect of ſuch a mode of action will be that there may be ſeveral neutral points in an imperfect conductor, and ſeveral overcharged and undercharged portions, and hence its action on diſtant bodies may be extremely various. The formula $\frac{fr-gr'+hr''-ir'''}{Q}$, where f, g, h, i, expreſs the different portions in oppoſite ſtates, and r, r', r'', r''', the repulſion at different diſtances, may be conveniently employed to denote the action in ſuch circumſtances. Hence, if another body be placed in the direction of the axis, it will be attracted at one diſtance, repelled at a greater, again attracted at a ſtill greater diſtance, and ſo alternately.

The obſtruction may not be conſiderable, and then the action of the neighbouring overcharged body will produce a deficiency in the proximate part of the conductor, a redundancy farther on, then a deficiency, and ſo on. Preſently theſe will ſhift, and ſucceſſively diſappear at the farther end, and the body will remain with only one neutral point. A greater obſtruction will leave the body with more than one neutral point, and the number of theſe will be in proportion to the obſtruction.

347 Induced electricity may become permanent in imperfect conductors. The removal of an overcharged body from the vicinity of conductors will have different reſults according as the conductors are perfect or imperfect, that is, according as there is obſtruction or not. In the former caſe,

caſe, the electricity induced by the vicinity of the overcharged body will be inſtantly deſtroyed on the removal of the body. But where there is an obſtruction acting, though, on the removal of the body, the forces that tend to reſtore the equilibrium in the conductor begin to act, and reſtore it in part, they can never do this completely; for when the force by which a particle is propelled from an overcharged part to one undercharged is juſt ſufficient to balance the obſtruction, it will remain in that ſtate of diſtribution at which it had arrived. We may expect then, that imperfect conductors will retain a part of their induced electricity.

On the removal of the electrifying body, the electric appearances induced by it in the conductor will diſappear in a contrary order to that in which they were produced, and they will be left in a ſtate of unequal diſtribution, or with a degree of electric power, proportioned to their imperfection as conductors.

We have now given an account of the principal conſequences of the theory of Æpinus, a theory which till of late was little known in Britain, owing probably to the very lame and imperfect account given of it by Dr Prieſtley in his popular work on electricity. More juſtice has been done to this theory by Mr Cavendiſh, who before he ſaw M. Æpinus's work had framed an hypotheſis of his own upon very ſimilar principles. Mr Cavendiſh's paper, in which he has treated this ſubject in a very able and learned manner, appeared in the 61ſt vol. of the Phil. Tranſ.

To this paper we ſhall be much indebted preſently; but in the mean time we ſhall only extract from it the hypotheſis, which is as follows.

348 Cavendiſh's hypotheſis.

There is a ſubſtance which we call the electric fluid, the particles of which repel each other, and attract the particles of all other matter, with a force inverſely as ſome leſs power of the diſtance than the cube; the particles of all other matter alſo repel each other, and attract thoſe of the electric fluid, with a force varying according to the ſame power of the diſtances. Or, to expreſs it more conciſely, if you look upon the electric fluid as a matter of a contrary kind to other matter, the particles of all matter, both thoſe of the electric fluid and of other matter, repel particles of the ſame kind, and attract thoſe of a contrary kind, with a force inverſely as ſome leſs power of the diſtance than the cube.

For the future, he would be underſtood never to comprehend the electric fluid under the word matter, but only ſome other ſort of matter.

It is indifferent whether we ſuppoſe all ſorts of matter to be endued in an equal degree with the foregoing attraction and repulſion, or whether you ſuppoſe ſome ſorts to be endued with it in a greater degree than others; but it is likely that the electric fluid is endued with this property in a much greater degree than other matter; for in all probability, the weight of the electric fluid in any body bears but a very ſmall proportion to the weight of the matter; but yet the force with which the electric fluid therein attracts any particle of matter muſt be equal to the force which the matter therein repels that particle; otherways the body would appear electrical, as will be ſhown hereafter.

To explain this hypotheſis more fully, ſuppoſe that one grain of electric fluid attracts a particle of matter at a given diſtance with as much force as *n* grains of any matter, lead for inſtance, repel it: then will one grain of electric fluid repel a particle of electric fluid with as much force as *n* grains of lead attract it; and one grain of electric fluid will repel one grain of electric fluid with as much force as *n* grains of lead repel *n* grains of lead.

All bodies, in their natural ſtate with regard to electricity, contain ſuch a quantity of electric fluid interſperſed between their particles, that the attraction of the electric fluid in any ſmall part of the body in a given particle of matter, ſhall be equal to the repulſion of the matter in the ſame ſmall part, in the ſame particle.

A body in this ſtate is ſaid to be ſaturated with electric fluid; if the body contains more than this quantity of electric fluid, he calls it overcharged; if leſs, he calls it undercharged.

Sect. III. *Of the Theory of two Fluids.*

349 This theory originated, as we have ſaid, in M. du Faye's diſcovery of the different electricities produced by rubbing glaſs and ſealing-wax.

Let us ſuppoſe that there are two electric fluids, which have a ſtrong affinity for each other, while, at the ſame time, the particles of each are ſtrongly repulſive of each other. Let us ſuppoſe theſe two fluids in ſome meaſure equally attracted by all bodies, and exiſting in intimate union in their pores; and while they continue in this manner to exhibit no mark of their exiſtence, let us ſuppoſe that the friction of an electric produces a ſeparation of theſe two fluids, cauſing (in the uſual method of electrifying) the vitreous electricity of the rubber to be conveyed to the conductor, and the reſinous electricity of the conductor to be conveyed to the rubber. The rubber will then have a double ſhare of the reſinous electricity, and the conductor a double ſhare of the vitreous; ſo that, upon this hypotheſis, no ſubſtance whatever can have a greater or leſs quantity of electric fluid at different times; the quality of it only can be changed.

The two electric fluids being thus ſeparated, will begin to ſhow their reſpective powers, and their eagerneſs to ruſh into re-union with each other. With whichever of theſe fluids a number of bodies are charged, they will repel one another: they will be attracted by all bodies, which have a leſs ſhare of that particular fluid with which they are loaded; but will be much more ſtrongly attracted by bodies which are wholly deſtitute of it, and loaded with the other. In this caſe, they will ruſh together with great violence.

On this theory, the electric ſpark conſiſts of both the fluids ruſhing in contrary directions, and making a double current. When, for inſtance, the finger is preſented to a conductor loaded with vitreous electricity, it diſcharges it of part of the vitreous, and returns ſo much of the reſinous, which is ſupplied to the body from the earth. Thus both the bodies are unelectrified, the balance of the two powers being reſtored.

When the Leyden phial is preſented to be charged, and conſequently the coating of one of its ſides is connected with the rubber, and that of the other with the conductor; the vitreous electricity of that ſide which is connected with the conductor is tranſmitted to that which is connected with the rubber, which returns an equal quantity of its reſinous electricity; ſo that all the vitreous electricity is conveyed to one of the ſides, and all the reſinous to the other. Theſe two fluids being thus ſeparated, attract each other very ſtrongly through the thin ſubſtance of the intervening glaſs, and ruſh together with great violence, whenever an opportunity is preſented, by means of proper conductors. Sometimes they will force a paſſage through the ſubſtance of the glaſs itſelf; and in the mean time, their mutual attraction is ſtronger than any force that can be applied to take away either of the fluids ſeparately.

Dr Prieſtley gives the following view of the comparative merits of this theory and that of Dr Franklin.

"In the firſt place, (ſays he), the ſuppoſition itſelf of two fluids, is not quite ſo eaſy as that of one, though it is far from being diſagreeable to the analogy of nature, which abounds with affinities, and in which we ſee innumerable inſtances of ſubſtances formed, as it were, to unite and counteract one another.

The two fluids being ſuppoſed, the double current from the rubber to the conductor, and from the conductor to the rubber, is an eaſy and neceſſary conſequence. For if, on the common ſuppoſition, the action of the rubber puts a ſingle fluid into motion in one direction, we might expect, that if there were two fluids, which counteracted each other, they would, by the ſame operation, be made to move in contrary directions. And a perſon that has been uſed to conceive that a ſingle fluid may be made to move either way, viz. from the rubber to the conductor, or from the conductor to the rubber at pleaſure, according as a rough or a ſmooth globe is uſed, can have much leſs objection to this part of the hypotheſis.

Admitting then this different action of the rubber and the electric upon the two different fluids, the manner of conveying electric atmoſpheres, or powers, to bodies is the ſame on this as on any other theory; and it is apprehended that the phenomena of negative electricity are more eaſily conceived by the help of a real fluid, than by no fluid at all. Indeed Dr Franklin himſelf ingenuouſly acknowledges, that he was a long time puzzled to account for bodies that were negatively electrified, repelling one another; whereas M. du Faye, who obſerved the ſame fact, had no difficulty about it, ſuppoſing that he had diſcovered another electricity, ſimilar, with reſpect to the properties of elaſticity and repulſion, to the former.

By this double action of the rubber, the method of charging a plate of glaſs is exceeding eaſy to conceive. Upon this hypotheſis, all the vitreous electricity quits its union with the reſinous on the ſide communicating with the conductor, and is brought over to the ſide communicating with the rubber; which, by the ſame operation had been made to part with its reſinous electricity in return.

All the vitreous electricity being thus brought to one ſide of the plate of glaſs, and all the reſinous to the other, the phenomena of the plate while ſtanding charged, or diſcharged, are perhaps more free from all difficulty than upon any other hypotheſis. When one of the ſides of the glaſs is conceived to be loaded with one kind of electricity, and the other with the other kind; the ſtrong affinity between them, whereby they attract each other with a force proportioned to their nearneſs, immediately ſupplies a ſatisfactory reaſon, why ſo little of either of the fluids can be drawn from one of the ſides without communicating as much to the other. Upon this ſuppoſition, that conſequence is perhaps more obvious, than upon the ſuppoſition of one half of the glaſs being crowded with the electric matter, and the other half exhauſted. In the former caſe, every attempt to withdraw the fluid from one of the ſides, is oppoſed by the more powerful attraction of the other fluid on the oppoſite ſide. On the other hypotheſis, it is only oppoſed by the attraction of the empty pores of the glaſs.

Laſtly, The exploſion upon the diſcharge of the glaſs has as much the appearance of two fluids ruſhing into union, in two oppoſite directions, as of one fluid proceeding only in one direction. The ſame may be ſaid of the appearance of every electric ſpark, in which, upon this hypotheſis, there is always ſuppoſed to be two currents, one from the electric, or the electrified body, and the other to it.

I do not ſay, continues Dr Prieſtley, that the bur which is uſually ſeen on both ſides of a quire of paper pierced by an electric exploſion, and the current of air flowing from the points of all bodies electrified negatively as well as poſitively, are material objections to the doctrine of a ſingle fluid. But upon the ſuppoſition of two fluids and two currents, the difficulty for accounting for theſe facts would hardly have occurred.

It is almoſt needleſs to obſerve, that the influence of points is attended with exactly the ſame difficulty upon this theory, as upon the other. It is equally eaſy, or equally difficult, to ſuppoſe one fluid to enter and go out at the point of an electrified conductor at different times, as to ſuppoſe, that, of two fluids, one goes out, and the other goes in, at the ſame time.

That bodies immerged in electric atmoſpheres muſt acquire the contrary electricity, is quite as eaſy to ſuppoſe upon this, as upon any other hypotheſis. For, in this caſe, ſuppoſe the electrified body to be poſſeſſed of the vitreous electricity, all the vitreous electricity of the body which is brought near it will be driven backwards to the more diſtant parts, and all the reſinous electricity will be drawn forwards. And, when the attraction between the two electricities in theſe different bodies is ſo great as to overcome the oppoſition to their union occaſioned by the attraction of the bodies that contained them, the form of their ſurfaces, and the reſiſtance of the interpoſing medium, they will ruſh together; an electric ſpark will be viſible between them; and the electricity of both will appear to be diſcharged; the prevailing electricity of each being ſaturated with an equal quantity of the oppoſite kind, from the other body.

This hypotheſis will likewiſe eaſily account for the difficulty of charging a very thick plate of glaſs, and the impoſſibility of charging it beyond a certain thickneſs; for theſe fluids, at a greater diſtance, will attract one another leſs forcibly, and at a certain ſtill greater diſtance will not attract at all."

Dr Prieſtley makes the following anſwer to the principal objection that may be urged againſt this theory.

"If it be aſked (ſays he), why the two fluids meeting on the ſurface of the globe, or in the electric exploſion, do not unite by means of their ſtrong affinity, and

and make no further progreſs; it may be anſwered, that the attraction between all other bodies and the particles of both theſe fluids, may be ſuppoſed to be at leaſt as ſtrong as the affinity between the fluids themſelves; ſo that the moment any body is diſpoſſeſſed of one, it may recruit itſelf to its uſual point of ſaturation, from the other.

Beſides, in whatever manner it be that one of the electric fluids is diſlodged from any body (ſince upon every theory the two electricities are produced at the ſame time) the oppoſite electricity will, by the ſame action, be diſlodged from the other ſubſtance. And whatever it be that diſlodges the fluid from any ſubſtance, it will be ſufficient to prevent its return; conſequently, ſuppoſing both the ſubſtances neceſſarily to have a certain proportion of electric matter, each may be immediately ſupplied from that which was diſlodged from the other.

The rubber, therefore, at the time of excitation, gives its vitreous electricity to that part of the ſmooth glaſs againſt which it has been preſſed, and takes an equal quantity of the reſinous in return. The glaſs being a non-conductor, does not allow this additional quantity of electricity to enter its ſubſtance. It is therefore diffuſed upon the ſurface, and, in the revolution of the globe is carried to the prime conductor. There it repels the vitreous, and violently attracts the reſinous electricity; and (the points of the conductor favouring the mutual tranſition), the vitreous, which abounds upon the globe, paſſes to the conductor; and the reſinous, which abounds upon the neareſt parts of the conductor, ruſhes upon the globe. There it mixes with, and ſaturates what remained of the vitreous electricity on the part on which it flows, and thereby reduces it to the ſame ſtate in which it was before it was excited. Every part of the ſurface of the globe performs the ſame office, firſt exchanging electricities with the rubber and then with the conductor.

The ſolution of this difficulty will alſo ſolve that of the electric exploſion, in which there is a colliſion, as it were, of the two fluids, while yet they completely paſs one another. For ſtill each ſurface of the glaſs may be ſuppoſed to require its certain portion of electric matter, and therefore cannot part with one ſort without receiving an equal quantity of the other. It muſt be conſidered alſo, that the air through which the fluids paſs, has already its natural quantity of electricity, ſo that being fully ſaturated, it can contain no more, and that the two fluids only ruſh to the places from which they had been forcibly diſlodged, and where the greater body of the oppoſite fluid waits to embrace them."

351 Defence of the theory of two fluids by M. Tremery.

Although, in our explanation of electrical phenomena, we ſhall adopt the theory of Æpinus and Cavendiſh, it is proper to obſerve that this theory does not univerſally prevail among the electricians of the preſent day. The hypotheſis of Du Fay, or the theory of two fluids, is ſtill maintained by ſeveral, eſpecially on the continent. This theory has lately found two ſtrenuous advocates in France, M. M. Hauy and Tremery.

Their principal objection to the theory of Æpinus ſeems to be founded on that part of his hypotheſis with which Æpinus himſelf was not perfectly ſatisfied, but which (in N° 321.) we have attempted to defend, viz. his introduction of a repulſive force among the particles of matter in a body.

"In fact, (ſay they), the ſuppoſition of a ſingle fluid of which the particles mutually repel each other, and are attracted by the particles of matter in all known bodies, gives riſe to many diſtinct forces, which cannot be in equilibrio, and which, by their mode of acting, are ſuch, that two bodies which are in their natural ſtate, and which are not attracted by any other force beſides that of electricity, muſt tend towards each other.

"The ſuppoſition of a repulſive force among the particles of matter in ſolid bodies becomes unneceſſary if we conceive the electric fluid as compoſed of two fluids, of which one poſſeſſes the property which Æpinus attributes to the particles of matter in the body. It is much better to admit a repulſion at a diſtance among the particles of two peculiar fluids, which, like all others, repel each other, even in contact, than to conceive ſuch a repulſion to exiſt among the particles of bodies that are in their nature ſolid. Thoſe philoſophers who endeavour to explain all the phenomena on the principle of a ſingle fluid, believed themſelves that its particles repelled each other at a diſtance, as from one ſurface of the Leyden phial to the other; and as what we call *action at a diſtance*, is properly no more than a fact on which we ground a theory, without inquiring what is the cauſe which furniſhes the point of difference, it is ſufficient that the manner in which we conceive this fact enables us to adapt it to our theory.

"Æpinus, who does not conceal his reluctance to admit that ſuch a force as that which we have mentioned can take place, would doubtleſs, (ſay theſe gentlemen), have adopted the hypotheſis of two fluids, if in his time the nature of the electrical phenomena had been better underſtood. But, at that period, the means of obſervation not being ſo perfect, experiments had not been made with that preciſion which characterize thoſe which we owe to M. Coulomb, and which have formed the foundation of thoſe important diſcoveries, by means of which this celebrated philoſopher, far exceeding the point at which Æpinus reſted, has carried the ſcience to a high degree of perfection, in that beautiful ſeries of memoirs, in which we muſt admire the addreſs with which he has availed himſelf both of experiment and calculation.

"Almoſt all the phenomena of electricity, then, ſeem to depend on the action of two peculiar fluids, which act in ſuch a manner, that the particles of each mutually repel *each other at a diſtance*, with a force which is *inverſely as the ſquare of this diſtance*, and attract the particles of the *other fluid* with the ſame force.

"It is of conſequence not to confound theſe two fluids with the two currents, the one of *influent* and the other of *affluent* matter, by which Nollet attempted to explain the phenomena. Theſe two *currents* belong to the ſame matter, and proceed, one *from* the conductor *towards* ſurrounding bodies, the other *from* theſe *towards* the conductor.

"We ſhall now endeavour to apply the hypotheſis of two fluids to the explanation of ſame phenomena which do not appear to agree with it, and which, by the manner in which we are accuſtomed to view them, ſeem to indicate that *vitreous* and *reſinous* electricity are only modifications of the ſame fluid.

"The experiments which ſeem to militate againſt our theory are very few, and may be reduced to the following.

352 Experiments that ſeem to militate againſt this theory.

“ *Exper.* 1.—If upon a cake of roſin we trace various deſigns with the point of a conducting ſubſtance, which is at one time electrified *poſitively*, or by *vitreous* electricity, and at another *negatively*, or by *reſinous* electricity; and if on this ſurface, thus electrified, we let fall a powder (G) properly diſpoſed; the deſigns thus rendered viſible will preſent characters peculiar to each ſpecies of electricity; thus ſhewing, according to the followers of Franklin and Æpinus, a ſuperabundance of electric fluid on one ſide and a deficiency on the other.

“ *Exper.* 2. When a conducting body terminating in a point, is electrified *poſitively* or by *vitreous* electricity, we perceive at the point a *luminous bruſh.* And if, all other things being equal, we ſubſtitute *negative* or *reſinous* electricity, the point is illuminated with a *ſtar* or *luminous point.*

“ According to the theory of poſitive and negative electricity, the *bruſh* indicates the tranſmiſſion of electric fluid *from* the body which is electrified poſitively, and the *ſtar* its entrance *into* the body which is negatively electrified.

“ *Exper.* 3.—When an electric exploſion takes place, all the electric fluid appears conſtantly to paſs *from* the body electrified *poſitively* to that which is electrified *negatively*.”

Here they cite the method of proving this, by piercing a card placed between the conducting balls of the *univerſal diſcharger.* (Vid. N° 196. Exp. 2.)

353 Explained by M. Tremery.

Theſe experiments, to which the theory of poſitive and negative electricity is happily applied, ſeem at firſt ſight inexplicable, according to the hypotheſis of two fluids. In fact, the particles of theſe two fluids being ſubject to the ſame laws, it ſeems,

1. That the deſigns traced on a cake of roſin, or other *ideo-electric* ſubſtance, with the point of a conductor, electrified at one time poſitively and at another negatively, ſhould on the whole be ſimilar.

2. That the luminous appearance obſerved at the ſummit of a pointed conductor, ought always to be the ſame, whatever be the *electrical ſtate* of the body.

3. That when an electric diſcharge has taken place, the vitreous and reſinous electricities, which mutually attract each other, ought to form a luminous train on *each* ſurface of the card, and the card ought to be perforated in a point equally diſtant from the two extremities of the balls of the diſcharger.

354 M. Tremery's explanation.

The following is the manner in which M. Tremery undertakes to explain theſe appearances.

“ The matter, (ſays he), to the action of which we attribute the electrical phenomena, being conſidered as compounded of two peculiar fluids, we may conclude that all bodies, conſidered in the relation which they bear to theſe fluids, do not poſſeſs the ſame properties; it is poſſible that *vitreous* and *reſinous* electricity may be of ſuch a nature, that, on the one hand, certain bodies, whether electrics or conductors, may have with reſpect to them different conducting powers; and on the other hand, that the *coercive power* (H) of *ideo-electrics* may vary according as they are oppoſed to the motion of particles proper to *vitreous* electricity, or to the motion of particles proper to *reſinous* electricity.

“ If, for inſtance, the air of the atmoſphere, in which electrical phenomena uſually take place, has an *incomparably* greater coercive power with reſpect to the reſinous electricity than it has to the vitreous, it would be very eaſy to explain the experiments that we have quoted. In this caſe, the reſinous electricity, becauſe of the almoſt infinite reſiſtance that the air would oppoſe to the motion of its particles, might be regarded as inherent in the ſurface of the bodies; whence it follows, that the ſame circumſtances would take place, as if the body electrified *reſinouſly* had the property of exerciſing by itſelf an attraction for the vitreous or *poſitive* electricity; a property which bodies in the negative ſtate are ſuppoſed to have, according to the theory of Franklin.

“ If now, the coercive power that we have ſuppoſed the air to have with reſpect to the reſinous electricity, could diminiſh ſo as to become equal to that which it has with reſpect to the vitreous, it would happen, that the ſigns which induce us to regard the vitreous electricity as poſitive, and the reſinous as negative, would diſappear, ſo that all the phenomena would ſeem to depend equally on the action of the two fluids that would be ſubject to the ſame law. In this new circumſtance, we ſhould obſerve a luminous pencil at the ſummit of a pointed conductor electrified *reſinouſly* or negatively, and when an electric diſcharge took place, the vitreous and reſinous electricities would appear to approach each other.

“ If, under theſe circumſtances, the coercive power of the air with reſpect to the vitreous electricity, ſhould increaſe, ſo as in its turn to become incomparably greater than what it had with reſpect to the reſinous electricity, it is evident, that the electric matter, acting in the midſt of ſuch a ſubſtance, would produce phenomena exactly ſimilar to thoſe with which we are acquainted; but, in this caſe, the vitreous or poſitive electricity would perform the office of the reſinous or negative, and *vice verſa*, and they would mutually exchange ſigns. A luminous pencil would appear at a point electrified negatively or reſinouſly, and a luminous ſtar at a poſitive or vitreouſly electrified point; and when two conducting bodies, electrified differently, were placed at a convenient diſtance, all the electric matter would appear to move *from* the negative body *towards* the poſitive *.”

CHAP. II. *A theoretical Explanation of the Phenomena of Electricity.*

SECT. I. *Of the Nature and Diſtribution of the Electric Fluid.*

355 Nature of the electric fluid.

BEFORE we enter on a theoretical explanation of the phenomena of electricity, it will not be improper to inquire

* *Journ. de Phyſique*, vol. liv. p. 357.

(G) This powder ſhould be compoſed of two ſubſtances, which, by their mutual friction againſt each other, are capable of receiving oppoſite electricities.

(H) By *coercive power* our author underſtands that which ideo-electrics or conductors oppoſe to the motion of the particles that are proper to each of the two fluids, that, according to this hypotheſis, are ſuppoſed to form by their union the *electric* fluid.

quire ſomewhat more at large into the nature of that ſubtile agent which we have diſtinguiſhed by the name of the electric fluid, and to notice ſome of the more plauſible opinions that have been hazarded on the ſubject.

One of the firſt queſtions that naturally ariſes from the very name of *fluid* is, *What proofs have we of the materiality of this power?*

Beſides the properties of attraction and repulſion, which are properties of matter, we have many other evidences that are very perſuaſive, as being more diſtinctly the objects of our ſenſes.

356 Proofs of its materiality.

1. The ſpark that appears when the electric power paſſes ſuddenly through the air or any other reſiſting medium, and the *ſnap*, by which it is accompanied, are ſtrong evidences in favour of the materiality of the power, by which they are produced. The noiſe of the ſpark is occaſioned by the ſudden impreſſion made on the air, or ſome other elaſtic fluid, through which the ſpark paſſes. When the air is confined in cloſe veſſels, as in a tube above water, no very durable effect is indeed produced on the water in the tube. But this is owing to the rapidity with which the expanſion and ſubſequent condenſation take place. Again, it is objected, that it is impoſſible to communicate motion to a very delicate lever, nicely balanced, by throwing on it any quantity of electricity. Some pretend to have done this; but, however, the impoſſibility of doing it is no argument againſt the materiality of the electric fluid; and we might juſt as well ſay, that a muſket ball is not material, becauſe it may be fired through a paper or thin board delicately ſuſpended, without imparting to them any part of its motion.

2. The light and heat accompanying the ſpark, are proofs of the materiality of the electric power. Theſe are chemical phenomena; and whether we conſider them as effects of the fluid as a ſimple, or as reſulting from its decompoſition, we conceive that they prove the materiality of the electric power, as completely as the materiality of caloric and light have been proved.

We are aware that this reaſoning will not ſatisfy thoſe philoſophers who deny the materiality of caloric and light; we know that much ſtreſs is laid on the experiments of Count Rumford, as completely ſubverſive of the materiality of heat, experiments that could even ſtagger the opinion of a Robiſon. Without deſiring in the leaſt to detract from the merit of that ingenious and able experimentaliſt, for whom we entertain a very high eſteem, we muſt confeſs, that we do not conſider his experiments as warranting the concluſions that have been drawn from them, and we are ſtill diſpoſed to think the materiality of caloric and light as fully proved as can be expected, with reſpect to matter that is not abſolutely tangible.

357 Electricity ſuppoſed to be the ſame with caloric.

From the ſimilarity of the chemical effects of the electric fluid with thoſe of elementary fire or caloric, it was long ago (as we have ſhewn in the beginning of this Part) ſuppoſed, that they were the ſame, and this is ſtill the opinion of ſome electricians. We cannot here pretend to enter on a full diſcuſſion of this queſtion, but we ſhall briefly ſtate the arguments in favour of the identity of caloric, and the objections that we have to make to them.

Electricity is the ſame with caloric (ſay the advocates for their identity) becauſe,

1. Both produce the ſame chemical effects, expanſion, fluidity, inflammation, oxidation, &c.

2. Thoſe bodies that are the beſt conductors of caloric, as the metals, are alſo the beſt conductors of electricity; and glaſs, which is a very bad conductor of caloric, is one of the moſt perfect non-conductors of electricity.

358 Arguments againſt this ſuppoſition.

To the firſt argument for their identity, we ſhall reply in the words of M. Berthollet, who once conſidered them as the ſame, but from experiments was ſatiſfied that their effects were different.

"A wire of platina was ſubmitted to ſhocks which were nearly ſtrong enough to effect its combuſtion; and to be ſatisfied of this, a ſhock was excited, by which a great part of the wire was melted and diſperſed; afterwards the ſhocks employed were a little weaker, and immediately after each, the wire was touched to judge of the temperature it had acquired: a heat was felt, which was diſſipated in a few minutes, and which, at the utmoſt, was eſtimated to reſemble that of the boiling point of water. If electricity liquefied metals, and brought them into combuſtion by the heat it excites, the platina wire muſt after a ſhock, which differed but little from that which would have produced its diſperſion and its combuſtion, have approached the degree of temperature which occaſions its liquefaction: Now this degree, which is the moſt elevated that can be obtained, would, according to the valuation, more or leſs accurate, of Wedgwood, be 32277° of Fahrenheit.

"When the ſhock is ſufficiently ſtrong to deſtroy the aggregation of the platina wire, it begins by detaching moleculæ from its ſurface, which exhale like ſmoke; if it is ſtrong enough to produce combuſtion, the remains of the wire appear to be torn into filaments.

"A thermoſcope blackened with ink, and placed in the ſteam of a ſtrong electric ſpark, only experienced a dilatation which was nearly equal to one degree of Reaumur's thermometer, and this ſlight effect might depend on the oxidation of the iron of the ink; placed beſide the current, it did not ſhow any dilatation, although the air was neceſſarily affected by the electric action: it was the ſame when it was placed in contact with a metallic conductor, which received a ſtream leſs powerful than in the preceding experiments.

"A cylinder of glaſs filled with air, with an exciter at each of its extremities, to one of which was fixed a tube communicating with another cylinder filled with water, produced an impulſe at each ſhock, which raiſed the water more than a diameter above its level, but its effect was inſtantaneous.

"Theſe experiments ſeem to me to prove that electricity does not act on ſubſtances, and on their combinations, by an elevation of temperature, but by a dilatation which ſeparates the moleculæ of bodies. The ſlight heat obſerved in the platina wire, is only the effect of the compreſſion produced by the moleculæ which firſt experience the electric action, or which experience it in a greater degree; it muſt, therefore, be compared to that excited by percuſſion or compreſſion.

"If the dilatation was the effect of heat, that experienced by a gas, in the experiment related above, would not have been inſtantaneous; it would only have experienced a progreſſive diminution by cooling, as when its expanſion is owing to heat.

"In the experiment by which ammoniacal gas is decompoſed, the gas undoubtedly receives the electric action, and nevertheleſs it is not heated; and as ſoon as the decompoſition is finiſhed, its volume remains unchanged, becauſe the electric action which is employed in this experiment, is not ſufficiently energetic to cauſe a perceptible dilatation. No ſenſible dilatation is produced by a gas in a ſhock which is not very ſtrong, becauſe the impulſe not being gradual like the expanſion ariſing from caloric, and being excited inſtantaneouſly, the reſiſtance of the liquid becomes too great, and cannot be overcome unleſs the dilatation has great energy.

"An experiment of Dieman and his learned aſſociates confirms this explanation: they cauſed a ſhock to paſs through lead placed in a veſſel filled with azotic gas, which could not oxidate it; it was reduced into powder retaining all its metallic properties: If it had experienced a liquefaction ſimilar to the action of heat, it would have cooled gradually, and would have congealed into one, or at leaſt into ſeveral maſſes.

"When a metal is ſubmitted to the electric action, the effects produced immediately by the electricity muſt be diſtinguiſhed from thoſe which are owing to its oxidation: the firſt are limited to the diminution or deſtruction of the effects of the force of coheſion, to removing and diſperſing the moleculæ (if by this a little heat is diſengaged, it is only owing to the compreſſion ſuſtained by ſome of the parts); but thoſe which are occaſioned by the oxidation, produce a high degree of heat, and then the effects aſſume all the appearances of an ordinary combuſtion: hence it ariſes, that the moſt oxidable metals are thoſe which become red with the greateſt facility, and which muſt ſhew the properties of a metal liquefied by heat.

"Electricity favours this oxidation in as much as it diminiſhes the force of coheſion; it is thus that an alkali renders the action of ſulphur on oxygen much more powerful, by deſtroying the force of coheſion oppoſed to it, and that a metal diſſolved in an amalgam, is oxidated much more eaſily than when it is in a ſolid ſtate. It is only by deſtroying the effects of the force of coheſion that heat itſelf produces the oxidation of metals; but the expanſive action of electricity will have a great advantage over that of caloric, becauſe its action is confined to the ſolid which it encounters in its courſe, ſo that the gas itſelf will not experience a dilatation in oppoſition to the condenſation which accompanies the combination: To this circumſtance may be applied what is obſerved in the action of hydrogen gas, which is capable of completely reducing an oxide of iron placed in the focus of a burning glaſs, although water, whoſe two elements receive the heat equally, is decompoſed by this metal [*]."

To the ſecond argument we ſhall anſwer, that though in the inſtance of metals it is correct, in ſo far as that theſe bodies are the beſt conductors, both of caloric and electricity, there are however, bodies that conduct caloric very well, but either do not *conduct* electricity, or do it very imperfectly.

Even in the caſe of metallic bodies, ſo far as can be inferred from the imperfect experiments that have been made on their comparative conducting power, it ſhould appear that the order of their conducting power, with reſpect to caloric, is not the ſame as that with reſpect to electricity.

Farther, caloric takes ſome time to paſs through the beſt conductors, while the electric fluid pervades the longeſt with inconceivable velocity.

Again, if electricity were the ſame with caloric, they ſhould mutually produce the ſame effects, and ſhould exiſt ſimultaneouſly. But this is by no means the caſe; a body may be ſtrongly electrified without being ſenſibly increaſed in temperature, and ſo far is heat from producing electricity (except in a few inſtances), that where the former is preſent in any conſiderable degree, the latter is deſtroyed.

Laſtly, the mode in which electricity and caloric paſs along conductors is, we think different. Caloric ſeems undoubtedly to penetrate their *ſubſtance*, while electricity appears not to extend beyond the ſurface, except it meet with ſome reſiſtance. The following experiment is uſually adduced to prove that electricity pervades the ſubſtance of conductors.

359
Whether the electric fluid pervades the ſubſtance of conductors.

Take a wire of any kind of metal, and cover part of it with ſome electric ſubſtance, as roſin, ſealing-wax, &c. then diſcharge a jar through it, and it will be found that it conducts as well as without the electric coating. This, ſays Mr Cavallo, proves that the electric matter paſſes through the ſubſtance of the metal, and not over its ſurface. A wire, adds he, continued through a vacuum, is alſo a convincing proof of the truth of this aſſertion. Even here, however, the proof, if impartially conſidered, will be found very defective. It is a fact agreed upon by all philoſophers, that bodies which to us are apparently in contact, do nevertheleſs require a very conſiderable degree of force to make them actually touch one another. Dr Prieſtley found that a weight of ſix pounds was neceſſary to preſs 20 ſhillings into cloſe contact, when lying upon one another on a table. A much greater weight was neceſſary to bring the links of a chain into contact with each other. It cannot be at all incredible, therefore, that a wire, though covered with ſealing-wax or roſin, ſhould ſtill remain at ſome little diſtance from the ſubſtance which covers it.

M. Coulomb proves that in an overcharged conducting body, the fluid does not penetrate into its ſubſtance, but diffuſes itſelf merely over the ſurface.

By means of a very delicate electroſcope, he examined pits made in a conducting body of various depths, and found that in the ſhalloweſt of them there was no ſenſible electricity; whence he naturally draws the concluſion, that the electricity in ſuch bodies does not extend beyond the ſurface. The reader may ſee a deſcription of the electroſcope employed, and a detail of the experiments in the Memoirs of the French Academy for 1786, p. 72, or the *Journal de Phyſique*, vol. ii. (of the ſeries by Delametherie), p. 236.

Dr Robiſon repeated Coulomb's experiments with the ſame reſults.

360
Electricity differs from light.

Another opinion that has been maintained with reſpect to electricity, is that it is the ſame with *light*. The principal argument for the identity of electricity and light ſeems to be that bodies are impregnated with the latter by means of the former, and indeed that light commonly appears when the electric fluid paſſes in any quantity from one body to another.

Another reaſon given for their identity, is, that both move with inconceivable velocity.

A ſtrong argument againſt the identity of light and electricity,

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[*] *Nicholſon's Journ.* 8vo, vol. viii.

electricity, is that the former paſſes through glaſs and other tranſparent electrics, which ſeem to be impermeable to the electric fluid.

As to the impregnation of opaque bodies with light by means of electricity, this is the effect of chemical decompoſition, as will preſently appear, and is really produced by light itſelf.

361 Electric fluid probably a compound.

What has been now ſaid is, we think, ſufficient to prove, that the electric fluid is neither caloric nor light. But the appearance of caloric and light, in many caſes, ſhews that there is an intimate connection between them and the electric fluid. In ſhort, they ſeem to form part of its compoſition; and we are inclined to conſider it as a compound, containing caloric and light, and probably ſome peculiar conſtituent, to which we give the name of electricity. This opinion is not new; it was the hypotheſis of Mr James Ruſſel, who filled the natural philoſophy chair at Edinburgh, above thirty years ago.

362 Hypotheſis of Profeſſor Ruſſel.

Mr Ruſſel conſidered the electric fluid as a compound of ſeveral others, containing particularly elementary fire, from which it derived its great elaſticity or power of repulſion. The elaſticity of the electric fluid he ſuppoſed to differ from that of air, in acting at a diſtance; whereas the action of the air is only on adjoining particles. Hence bodies that contain more electric fluid than the ſpaces around them, have a tendency to repel each other.

Mr Ruſſel conſidered the characteriſtic ingredient of the compound, i. e. the electricity, as united to the other conſtituents by chemical affinity, or, as it was then called, *Elective Attraction*. This attraction acts at all diſtances, but not exactly according to the ſame law, as the repulſive power of the elaſtic fluid; and in general, while in this ſtate of compoſition, counteracts the repulſion of the electric particles. Again, the electricity attracts the particles of other bodies, but with different degrees of affinity. Non-electrics or conductors are attracted by it at all diſtances, but electrics only at very ſmall and imperceptible diſtances, and at ſuch diſtances only its own particles attract each other.

Hence this compound fluid repels its own particles at all conſiderable diſtances, but attracts them when very near. It alſo attracts conductors at all diſtances, but electrics only when very near. The appearances of light and heat were conſidered by Mr Ruſſel as proofs of a partial decompoſition, and as evincing the preſence of elementary fire: the peculiar odour of the electric ſpark, and the effect produced in certain inſtances on the organ of taſte, were alſo regarded as proofs of chemical decompoſition, and of the compound nature of the electric fluid.

Again, conducting bodies containing electric fluid, if forced very near, attract each other; otherwiſe they repel each other. Electrics contain the electric fluid in conſequence of the electricity exiſting in the compound: a part of this muſt be attached to the ſurface of the electric, but not in its elaſtic ſtate, ſince when brought ſo near as to be attracted, its particles are ſubjected to their own mutual action, and hence the repulſion occaſioned by its combination with the other ingredient of the fluid is overcome by the redoubled attraction; the electric fluid is thus partially decompoſed, and the electricity attaches itſelf to the ſurface of the electric. Thus the electric fluid may appear in two ſtates; elaſtic when entire, and unelaſtic when partially decompoſed.

The electricity may be rendered unelaſtic in ſeveral ways, as by friction, by which the electric fluid contained in the air is forced into cloſer contact, thus producing a decompoſition of the fluid, and cauſing its electricity to unite with the ſurface of the rubbed body. This operation may be compared to the forcible wetting of a dry ſponge, or of ſome powder, as that of the puff ball, which, when dry, do not eaſily imbibe moiſture; but when wetted by mechanical compreſſion, retain it very forcibly. The electricity unites with bodies in this way during ſeveral operations of nature, as in the melting and cooling of ſome ſubſtances in contact with electrics; and it may be thus forcibly united to the ſurface of electrics by means of metallic coatings, into which the fluid is forced by the ſkilful management of its mutual repulſions. This operation, again, was compared by Mr Ruſſel to the condenſation of the moiſture of humid air on a cold pane of glaſs; and the evacuation of fluids from the other ſide of the coated pane he compared to the evaporation of the moiſture from the other ſide of the cold pane, in conſequence of the heat that was extricated from the condenſed vapour.

The analogy that exiſts between electricity and caloric, has induced ſome to apply to the former the doctrine of capacity, ſo ingeniouſly applied to caloric by Dr Crawford. This doctrine ſeems to be one of the fundamental principles of Mr Wilkinſon's theory of electricity; the ſubſtance of which is contained in the following extract.

363 Mr Wilkinſon's hypotheſis.

"From ſome experiments, I am induced to ſuppoſe, that electricity is univerſally diffuſed, but not equally; that thoſe bodies are the beſt conductors which contain the greateſt quantity, and thoſe the beſt non-conductors which contain the leaſt.—Thus metallic bodies are the beſt conductors; all fluids, except air and oil, are alſo conductors. The diſpoſition in the body to retain electricity may be termed its capacity.

When conducting bodies undergo any change, if by ſuch change their capacities become altered, then ſigns of electricity are evinced.

If the change ſhould be of ſuch a nature, that their capacity for electricity becomes increaſed, the ſubſtance will be in a ſtate of abſtracting it from ſurrounding bodies, and therefore will evince negative ſigns; the ſame as frigorific mixtures produce negative ſigns of heat.

If, in the change it undergoes, the capacity of the ſubſtance for electricity is diminiſhed, it gives out a portion of its natural quantity, and evinces poſitive ſigns, or a ſtate of ſuperabundance.

When any ſubſtance, in the change it undergoes, gives out electricity, it becomes proportionally diminiſhed in its conducting powers; ſo, on the contrary, when it acquires an increaſe, it increaſes alſo its powers as a conductor.

Thus a metallic ſubſtance, which is a good conductor, when oxidated is a very imperfect one. In the change from its reguline ſtate to a calx, electricity is given out.

This

Theory of Electricity.

This capacity for electricity is not regulated by any known laws, ſuch as the denſities or the ſpecific gravities of the bodies.

In many ſubſtances, the conducting power ſeems to depend on the addition of other principles; thus wood, when a conductor, is ſo in conſequence of the moiſture it contains; when deprived of it by drying, it reſiſts the paſſage of electricity.

What this peculiar change may be, is difficult to conceive; but when electric bodies become partial conductors, it ſeems to be effected by the agency of heat.

When the preſſing action is very conſiderable, as in the caſe of metallic bodies, great quantities of heat are extricated. Thus a nail, when ſtruck violently, ſoon exhibits ſigns of conſiderable warmth; the caloric infuſed in its interſtices is exuded on the ſurface, in conſequence of the approximation of the conſtituent particles of the iron.

Whether the caloric diffuſed in the interſtices, or combined with the body, is given out by preſſure, is a fact difficult to determine. Thoſe ſubſtances which are non-conductors, and conſequently capable, from excitation, of giving out ſigns of electricity, do not all of them loſe their power, when freed from the rubbing action. Thoſe bodies which are uſually termed reſinous, continue for a certain ſpace of time in their conducting ſtate, until they are equalized with the ſurrounding air; and, continuing in a diſpoſition to abſtract electricity from ſurrounding bodies, will therefore evince negative ſigns (*1*)".

* *Wilkinſon's Elements of Galvaniſm*, vol. ii.

364 Obſervations by Mr G. Morgan.

The doctrine of bodies having different capacities for electricity was ingeniouſly employed by Mr G. Morgan to account for the effects produced on electrics by friction.

" If (ſays he) we admit the corporeal nature of that which is hence with accuracy called the electric fluid, let us attend to the neceſſary conſequences of what we admit:—1ſt. That the electric fluid, like all other corporeal ſubſtances, is capable of attracting, and of being attracted. 2d. That in conſequence of this capacity, it enters into an union with other bodies, and that as the nature of the ſubſtances to which it is united may vary, ſo the degree of force by which it is united may ſhow an equal variety. 3d. That when the electric fluid is ſeparated from any body, this ſeparation muſt be the effect of leſſening the force by which it was united to that body, and thus giving the attractive force of another body the ſuperiority; or it muſt be the effect of very much increaſing the force of the third body, and thus deſtroying the equilibrium.

Suppoſe that any body, A, ſhould be capable of uniting to itſelf, or ſuppoſe the law of its conſtitution were ſuch as to admit of its attaching, fifty particles of the electric fluid to itſelf, when near or in contact with another body, B, which likewiſe has an attraction to thoſe particles; now, in caſe any ſuch change ſhould take place as would add twenty particles to B, and leave thirty only in A, this change, it is evident, muſt proceed either from a diminution of A's attracting force, or from an adequate increaſe of force in B. Having deduced, from the corporeal nature of the electric fluid, ſuch conſequences as ſhow that when it is ſeparated from a body, it muſt proceed from a diminution of attractive force in the body that yields, or an increaſe of the ſame force in the body that takes; let us now examine how friction is likely to be the cauſe of ſuch changes.

By attending to the nature of friction, we ſhall find it to be nothing more than a ſucceſſion of preſſure or contacts of the different parts of different ſubſtances againſt each other: and the queſtion in the preſent caſe is this;—whether contact is neceſſarily attended with a change of attractive force in the different ſubſtances which are brought together? or whether the cloſe union of a particle of ſilk, hair, leather, &c. to a particle of glaſs, may be attended with a change of capacity in thoſe bodies to retain the electric fluid?—If this queſtion be admitted, I think the particular mode in which friction operates is eaſily diſcovered.

Briefly my idea of the manner in which friction operates, is this: when two electrics are preſſed cloſely together, while they continue together, they become capable of taking more, or retaining leſs; and if this be allowed, I think the various appearances of bodies in a ſtate of excitation are eaſily accounted for.

However, it may be aſked, if the change produced in the ſurfaces of two bodies be the effect merely of bringing the bodies nearer together; why does not contact alone produce the ſame effect? I muſt anſwer, that the ſeveral inſtances of ſpontaneous electricity enumerated by Wilcke, Æpinus, and others, appear to me to be ſo many evidences of the preceding theory. In theſe inſtances we ſee the excitation of ſurfaces take place in ſuch circumſtances as will not rationally admit of any other cauſe than ſimple contact.

It is evident, I think, that contact alone is adequate to the production of electricity. I would add, that in the only caſe where contact may be applied moſt completely, electricity is produced in a moſt remarkable degree.—By Bennet's new electroſcope, we find that the ſlighteſt evaporation (which is certainly the union of watery with aërial particles) produces immediate ſigns of electricity. How rationally all the electrical appearances of our atmoſphere may be aſcribed to the ſame ſource, will be ſhown more fully hereafter.

Before I quit this ſubject, I would explain to you the reaſons why, in many caſes, agreeably to the preceding hypotheſis, friction is neceſſarily much more powerful in its effects than preſſure.

Suppoſe

(*1*) Mr Coulomb endeavours to prove that the electric fluid is not diſtributed among conducting bodies in contact by chemical affinity, but merely by its repulſive motion.

When two bodies, equal and ſimilar, placed in contact, are tolerably perfect conductors, ſuch as the metals, the electricity communicated from one to the other is in an inſtant divided equally between them; but when one of the bodies is an imperfect conductor, as a plain of paper, it will take ſome time before the paper receives the half of the electricity of the metal. In all caſes, however, the electricity is equally divided. *Vid. Mem. de l'Acad. Roy. de Paris, pour* 1786. p. 69.

Suppoſe A to be a particle of ſilk, brought into contact with a particle of glaſs, which I call B; by the increaſe of attraction conſequent upon the union, the combined bodies become capable of attracting a portion of the fluid, which I ſay, is equal to five. Now A is no ſooner ſeparated from B, than another particle of ſilk comes in contact, and produces a ſimilar effect. The portion accumulated is now ten. A third comes into ſucceſſive contact with B, and adds to the accumulation; and while the rubbing goes on, a ſeries of ſucceſſive effects is produced by a ſeries of ſucceſſive unions and ſeparations; for A is no ſooner ſeparated from B, than it is brought into that ſtate in which it was before the union, and conſequently diſpoſed to part with what it gained by the union. Now if you ſuppoſe A and B, inſtead of being ſingle particles, to be ſurfaces, all of whoſe parts operate at the ſame time, you may eaſily perceive how the effect would be increaſed.

In the preceding caſe, I deſcribed the capacity of A and B to be enlarged by their union. If it had been leſſened, the ſubſequent effects would have been ſufficient; for, in ſuch a caſe, after the diſſolution of their contact, they would be diſpoſed to receive or retake what they had loſt by their union. But I will ſpeculate no longer on the conſequences of friction, as elucidated from the ſuppoſed corporeal nature of the electric fluid, and from the changes ſuppoſed to take place on the attractive force of different bodies when brought into very cloſe contact with each other *."

365 Brugnatelli ſuppoſes the electric fluid to be an acid.

Sig. Brugnatelli, from the chemical properties of the electric fluid, and, from ſeveral experiments which he has made upon the ſubject, concludes that it ſhould be ranked among the acids. This fluid, ſays he, reddens the tincture of turnſole, which as the fluid diſſipates returns again to a blue colour; it penetrates the metals, oxidates them, and produces hydrogen gas. In fine, it poſſeſſes all the properties of an acid. He therefore denominates it the *electric* or *oxi-electric acid*, and of courſe the ſalts which are formed by its combination with ſalifiable baſes, are called *electrats*. On ſome of theſe he makes the following obſervations.

1. The *electrat* of gold is formed of ſmall, brilliant, and tranſparent points.

2. The *electrat* of ſilver conſiſts of ſmall priſmatic cryſtals, terminated by ſix-ſided pyramids, which are limpid and tranſparent, and ſtrongly reflect the light. They are taſteleſs and inſoluble in water.

3. The *electrat* of copper conſiſts of cubical tranſparent cryſtals, which diſſolve in the acid with efferveſcence. The cryſtals are of a beautiful green colour.

4. The *electrat* of iron is of a reddiſh yellow colour, and opaque.

5. The *electrat* of zinc is opaque, and of a grayiſh colour.

The *electric acid*, according to this author, is not decompoſed, when it oxidates the metals, but the oxygen required for their oxidation, is derived from the water employed in his experiments.

366 Law of action of the electric fluid.

Having thus conſidered pretty fully the chemical nature of the electric fluid, we ſhall return to its mechanical properties, and endeavour to aſcertain the law by which its particles act on each other, and how it is diſtributed in bodies of various figures, and in various relations.

It was long a deſideratum among electricians to diſcover the law of action according to which the particles of the electric fluid attract and repel each other. Æpinus, we have ſeen, ſtates no other law than that the action decreaſes according as the diſtance increaſes. Mr Cavendiſh ſuſpected, but did not prove either by demonſtration or experiment, that the action of electricity was, like that of gravitation, inverſely as the ſquare of the diſtance.

Lord Stanhope attempted to prove that this was the law of electric action, both experimentally and mathematically, and concluded from the reſult of both his experiments and reaſoning, that the ſuppoſition was juſt. But Dr Robiſon did not conſider the experiment of Lord Stanhope, as ſufficiently accurate, or ſufficiently detailed, to warrant the concluſions that his Lordſhip had drawn *.

That eminent philoſopher, nearly 40 years ago, made a ſet of experiments for aſcertaining this law, and they were attended with reſults ſimilar to thoſe of Lord Stanhope.

367 Aſcertained experimentally by Dr Robiſon.

Dr Robiſon's experiments were made with the aſſiſtance of his excellent electrometer, which we have deſcribed in N° 206. The mode of uſing this inſtrument is as follows.

The body whoſe electricity is to be examined is connected with the electrometer by a wire, the end of which is inſerted into the hole at F, and made to touch the end of the needle. Now the index is to be turned to the right by the handle I, till it come to 90. In this poſition LA, and conſequently CB, is horizontal; and the moveable ball B reſts on A and moves with it. The balls being now electrified, the handle is turned back till the index arrive at 0, from which it ſet out. If during this motion the balls be noticed, it will be found that in ſome poſition of the index they will ſeparate. Bring them again together, and again ſeparate them, till the exact point of ſeparation be aſcertained. This will give their repulſion when in contact, or at the diſtance of their centres. Then turn the index ſtill more to the vertical poſition, and the balls will ſeparate ſtill more. Let an aſſiſtant now move the long index till it become parallel to the ſtalk of the electrometer, which will be known by its hiding the latter from his view. If the ſtalk be poiſed, by laying a weight of ſome grains on the cork ball D, till the ſtalk become horizontal and nicely balanced, we know exactly the weight that denotes the degree of repulſion that will cauſe the balls to ſeparate when in the horizontal poſition, by computing for the proportional lengths of BC and DC. Then, by a very ſimple computation, we ſhall find the weight denoting the degree of repulſion with which they ſeparate in any oblique poſition of the ſtalk, and again, by the reſolution of forces, we find the degree of repulſion with which the balls ſeparate when AL is oblique, and BC makes with it any given angle.

The intention of Dr Robiſon's experiments was to aſcertain the law of repulſion of two *ſmall ſpheres*, as whatever was the law of diſtribution of the particles in a ſphere, which we ſhall conſider preſently, the general action of its particles on thoſe of another ſphere will not differ materially from the law of action between two particles, if the ſpheres are very ſmall in proportion to their diſtance.

The reſult of the experiments was that the mutual repulſion

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* *Morgan's Lectures*, vol. i.

* *Mahon's Principles of Electricity*, Parts iv. v. and vi.

repulſion of two ſmall ſpheres, electrified either poſitively or negatively, was very nearly inverſely as the ſquare of the diſtance of their centres, or a little greater. Thus, if we expreſs the diſtance by x, the law of repulſion was as nearly as poſſible $\frac{1}{x^{2,06}}$. One of the balls being much larger than the other appeared to cauſe no difference in the reſults.

Repeating the experiment with balls electrified oppoſitely, and which of courſe attracted each other, the reſults obtained were not quite ſo regular; but the general reſult was a deviation from the above law rather leſs than in the preceding caſe, this being in defect, while that was in exceſs.

Sir Iſaac Newton has demonſtrated, (*Princip.* lib. i. pr. 74.) that if particles of matter act on each other with a force in the inverſe duplicate ratio of the diſtances, ſpheres compoſed of ſuch particles and of equal denſity at equal diſtances, will act on each other according to the ſame law. He has demonſtrated that the ſame holds in the caſe of hollow ſpherical ſhells, and that theſe act on each other in the ſame manner as if all their matter were crowded into their centres; and he has farther demonſtrated, that if the law of action between the particles be different from what has been ſtated, the action of ſpheres or ſpherical ſhells will alſo be different.

M. Coulomb of the French academy made a number of moſt valuable experiments for the purpoſe of aſcertaining this point, and obtained the ſame reſults.

This diſtinguiſhed academician has publiſhed in the memoirs of the Royal Academy at Paris for 1784, 1785, 1786, and 1787, papers which rank him very high among thoſe who have contributed to advance the ſcience of electricity.

In the Memoirs for 1785 appeared the papers that contain the experiments by which he proved the law of electric action. Theſe we cannot here pretend to detail, but the reſult is highly ſatisfactory. They were made with the aſſiſtance of a very delicate electrometer, the conſtruction of which we ſhall deſcribe under the article ELECTROMETER.

368 Approximating experiment.

The reader may ſatisfy himſelf very nearly of the truth of this law by the following ſimple experiment.

A, fig. 102. is the convex extremity of an excited ſurface. BC is a metallic rod, delicately ſuſpended on the point E. CF is deſigned to contain any weight which may be applied to the extremity of the rod. The apparatus ſhould be as light as poſſible, and is beſt made of reed and cork covered with tinfoil.

While the ſurface A is in an excited ſtate, B is brought within a certain diſtance of it, and the weight moved by its influence is carefully obſerved. A ſimilar obſervation is then made at a ſecond, a third, and a fourth diſtance.

Varieties will be diſcovered in the reſult of theſe obſervations, proceeding from the impoſſibility of keeping the ſurface for any conſiderable time in the ſame ſtate of excitation. Theſe varieties, however, are trifling; and in a vaſt number of experiments, the weight will diminiſh very nearly in the duplicate ratio of the increaſed diſtance.

We may now ſafely conclude that the law of electric action is like that of gravitation, ſo that electrified bodies attract or repel each other with a force that is inverſely as the ſquare of the diſtance. The aſcertaining of this important law is of infinite conſequence. It affords us a full conviction of the truth of the propoſitions reſpecting the action of bodies that are overcharged at one end, and undercharged at the other. It renders certain what we could formerly infer only from a reaſonable probability. We now ſee that the curve deſcribed in N° 338. muſt really have its convexity turned towards the axis, and that $Z+z'$ will always be greater than $Z'+z$.

369 Diſtribution of the electric fluid.

We now proceed to conſider the manner in which the electric fluid is diſtributed, when it is redundant or deficient in bodies; and for this purpoſe we cannot do better than lay before the reader the following ſeries of propoſitions, chiefly taken from Mr Cavendiſh's paper, but accommodated to the true law of action above laid down.

370 Fundamental propoſition.

LEMMA I.—Let the whole ſpace comprehended between two parallel planes, infinitely extended each way, be filled with uniform matter, the repulſion of whoſe particles is inverſely as the ſquare of the diſtance; the plate of matter formed thereby will repel a particle of matter with exactly the ſame force, at whatever diſtance from it it be placed.

For, ſuppoſe that there are two ſuch plates, of equal thickneſs, placed parallel to each other, let A, fig. 103. be any point not placed in or between the two plates; let BCD, repreſent any part of the neareſt plate; draw the lines AB, AC, and AD, cutting the furtheſt plate in *b*, *c*, and *d*; for it is plain that if they cut one plate, they muſt, if produced, cut the other: the triangle BCD, is to the triangle *bcd*, as AB^2 to Ab^2; therefore a particle of matter at A will be repelled with the ſame force by the matter in the triangle BCD, as by that in *bcd*. Whence it appears, that a particle at A will be repelled with as much force by the neareſt plate, as by the more diſtant; and conſequently will be impelled with the ſame force by either plate, at whatever diſtance from it it be placed.

COR. 1.—The ſame will be true of the action of plates of equal thickneſs and equal denſity, or of ſuch thickneſs and denſity as to contain quantities of matter or fluid proportional to their areas.

COR. 2.—The action of all ſuch ſections made by parallel planes, or by planes equally inclined to their axis, is equal.

COR. 3.—The tendency of a particle to a plane, or plate of uniform thickneſs and denſity, and infinitely extended, is the ſame, at whatever diſtance it be placed from the plate, and it is always perpendicular to it.

COR. 4.—This tendency is proportional to the denſity and thickneſs of the plate or plates jointly.

371 Diſpoſition in parallel plates.

Problem 1.—In fig. 104. let the parallel lines A*a*, B*b*, &c. repreſent parallel planes infinitely extended each way: let the ſpaces AD and EH be filled with uniform ſolid matter: let the electric fluid in each of theſe ſpaces be moveable and unable to eſcape: and let all the reſt of the matter in the univerſe be ſaturated with immoveable fluid. It is required to determine in what manner the fluid will be diſpoſed in the ſpaces AD and EH, according as one or both of them are over or undercharged.

Let AD be that ſpace which contains the greateſt quantity

quantity of redundant fluid, if both ſpaces are overcharged, or which contains the leaſt redundant matter, if both are undercharged; or if one is overcharged, and the other undercharged, let AD be the overcharged one. Then, firſt, There will be two ſpaces, AB and GH, which will either be entirely deprived of fluid, or in which the particles will be preſſed cloſe together; namely, if the whole quantity of fluid in AD and EH together, is leſs than ſufficient to ſaturate the matter therein, they will be entirely deprived of fluid; the quantity of redundant matter in each being half the whole redundant matter in AD and EH together: but if the fluid in AD and EH together is more than ſufficient to ſaturate the matter, the fluid in AB and GH will be preſſed cloſe together; the quantity of redundant fluid in each being half the whole redundant fluid in both ſpaces. 2dly, In the ſpace CD the fluid will be preſſed cloſe together; the quantity of fluid therein being ſuch as to leave juſt enough fluid in BC to ſaturate the matter therein. 3dly, The ſpace EF will be entirely deprived of fluid; the quantity of matter therein being ſuch, that the fluid in FG ſhall be ſufficient to ſaturate the matter therein: conſequently, the redundant fluid in CD will be juſt ſufficient to ſaturate the redundant matter in EF. And 4thly, The ſpaces BC and FG will be ſaturated in all parts.

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 their natural ſtate.

Cor. 2.—If the redundant fluid in the one be juſt ſufficient to ſaturate the redundant matter in the other, the two remote ſurfaces will be in their natural ſtate, all the redundant fluid being crowded in the ſtratum C*cd*D, and all the redundant matter being in E*ef*F.

372 Diſpoſition in a ſphere. Lemma II.—Let B D E *b d e*, and β δ ε, (fig. 105.) be concentric ſpherical ſurfaces, whoſe center is D: if the ſpace B*b* is filled with uniform matter, whoſe particles repel with a force inverſely as the ſquare of the diſtance, a particle placed anywhere within the ſpace C*b*, as at P, will be repelled with as much force in one direction as another, or it will not be impelled in any direction. This is demonſtrated in *Newt. Princip.* lib. i. prop. 70. It follows alſo from his demonſtration, that if the repulſion is inverſely as ſome higher power of the diſtance than the ſquare, the particle P will be impelled towards the centre; and if the repulſion is inverſely as ſome lower power than the ſquare, it will be impelled from the centre.

Problem 2.—Let the ſquare BDE, be filled with uniform ſolid matter, overcharged with electric fluid; let the fluid therein be moveable, but not able to eſcape from it; let the fluid in the reſt of infinite ſpace be moveable, and ſufficient to ſaturate the matter therein; and let the matter in the whole of infinite ſpace, or at leaſt in the ſpace BB, whoſe dimenſions will be given below, be uniform and ſolid: it is required to determine in what manner the fluid will be diſpoſed both within and without the globe.

Take the ſpace B*b*, ſuch that the interſtices between the particles of matter therein ſhall be juſt ſufficient to hold a quantity of electric fluid, whoſe particles are preſſed cloſe together ſo as to touch each other, equal to the whole redundant fluid in the globe, beſides the quantity requiſite to ſaturate the matter in B*b*; and take the ſpace BB, ſuch that the matter therein ſhall be juſt able to ſaturate the redundant fluid in the globe: then in all parts of the ſpace B*b*, the fluid will be preſſed cloſe together, ſo that its particles ſhall touch each other: the ſpace Bβ will be entirely deprived of fluid; and in the ſpace C*b*, and all the reſt of infinite ſpace, the matter will be exactly ſaturated.

Cor. 1.—If the globe BDE is undercharged, every thing elſe being the ſame as before, there will be a ſpace B*b*, in which the matter will be entirely deprived of fluid, and a ſpace Bβ in which the fluid will be preſſed cloſe together; the matter in B*b* being equal to the whole redundant matter in the globe, and the redundant fluid in Bβ being juſt ſufficient to ſaturate the matter in B*b*: and in all the reſt of ſpace the matter will be exactly ſaturated, exactly ſimilar to the foregoing.

Cor. 2.—The fluid in the globe BDE will be diſpoſed in exactly the ſame manner, whether the fluid without is immoveable, and diſpoſed in ſuch manner, that the matter ſhall be everywhere ſaturated, or whether it is diſpoſed as above deſcribed; and the fluid without the globe will be diſpoſed in juſt the ſame manner, whether the fluid within is diſpoſed uniformly, or whether it is diſpoſed as above deſcribed.

373 General repreſentation of the diſpoſition. Let BC, fig. 106. be a cylindrical conducting body, and A an overcharged body. Draw *b c* parallel to BC, and draw B*b*, C*c*, P*p*, &c. perpendicular to BC, to repreſent the uniform denſity of the fluid, when BC is in its natural ſtate; and let B*d*, C*r*, P*s*, &c. repreſent the unequal denſities at different points, while it is oppoſed to the overcharged body A. Now theſe ordinates will be bounded by a line *d n r*, cutting the line *b c* in *n*, a point in the line *n* N drawn perpendicular to N, the neutral point of the conductor. The whole quantity of fluid in BC will be repreſented by the parallelogram *b c*, CB; but this muſt be equal to the ſpace B C *r n d*; again, the redundant fluid in any portion, as PC or PN, may be repreſented by the ſpaces *p t r c*, or *t p n*, and the deficient fluid in any portion BQ, may be repreſented by the ſpace *b d v q*. Now, the action of BC on any body placed near it, will entirely depend on the ſpace contained between the curve line and the axis *b c*. With reſpect to this curve, the only circumſtance that we can aſcertain, is that variations of curvature at every point are proportional to the forces exerted by the ſpherical body A; and are, therefore, inverſely as the ſquares of the diſtances from A, as will be ſhewn preſently. The exact place of the point *n*, and the length of the ordinates, will vary according to the diameter of the conductor. We ſhall at preſent conſider only the ſimpleſt caſe, or that where the conductor is of no ſenſible diameter, like a very fine wire.

374 Diſtribution in a very ſmall canal nearly uniform. Let ſuch a ſlender conducting canal be repreſented by AE, fig. 107. and let B*b*, C*c*, E*e*, &c. repreſent the denſity of the contained fluid, this being kept in a ſtate of unequal denſity by its repulſion for ſome overcharged body. Now, a particle at C is impelled in the direction CE by all the fluid that is on the ſide of A; and it is impelled in the direction CA by all the fluid on the ſide of E. The moving force will ariſe from the difference of theſe repelling forces. When the diameter of the canal continues the ſame, this will ariſe from the difference of denſity only. Therefore, the force of the element at E may be expreſſed by the exceſs of D*d* above C*c* + the action at the diſtance CD.

Draw

Draw $\beta c \varepsilon$ parallel to AE; then the force of the element E may be expreſſed by the formula $\frac{d\partial}{c\partial^2}\dot{x}$, and this is the force repelling the particle in the direction CA.

Take CF=CD; the force at F will be expreſſed by $\frac{f\varphi}{c\varphi^2}\dot{x}$, or $\frac{f\varphi}{c\partial^2}\dot{x}$, and this foree alſo impels the particle in the direction CA. The joint action of the two is $\frac{d\partial+f\varphi}{c\partial^2}\dot{x}$. If bce were a ſtraight line, $d\partial+f\varphi$ would always be proportional to $c\partial$, and might be expreſſed by $m\times c\partial$, m denoting ſome number that expreſſes what part of $c\partial$ the ſum of $d\partial$ and $f\varphi$ is equal to, ſuppoſe $\frac{1}{10}$, $\frac{1}{20}$, $\frac{1}{30}$, &c. But in the preſent caſe $d\partial+f\varphi$ is not always proportional to $c\partial$, for $d\partial$ does not increaſe ſo faſt as $c\partial$, while $f\varphi$ increaſes faſter. We may, however, without any ſenſible error, expreſs the accelerating force tending towards A, in the neighbourhood of any point C, by $\frac{mc\partial}{c\partial^2}\dot{x}$, that is, by $m\frac{\dot{x}}{x}$, which is the fluxion of the area of a hyperbola HD′G, of which CC′ and CK are aſſymptotes. The whole action of the fluid between F and D may be expreſſed by the area C′CDD′H. Hence, the action of the ſmaller conceivable portion of the canal that adjoins to C on either ſide, or the difference of the actions of the two adjacent elements, is equal to the action of all beyond it. The ſtate of compreſſion is therefore ſcarcely affected by any thing at a ſenſible diſtance from C, and the denſity of the fluid in an indefinitely ſmall canal is uniform.

Having thus found that the fluid in very ſmall canals is very nearly of an uniform denſity, we may now proceed to examine the communication of electricity by means of conducting canals; which forms one of the moſt important parts of the theory.

375 Communication by ſtraight canals.

Let us ſuppoſe that the body A communicates by the canal EF, with another body D, placed on the contrary ſide of it from B, as in fig. 108. and let theſe two bodies be either ſaturated, or over or undercharged; and let the fluid within them be in equilibrio. Let now the body B be overcharged: it is plain that ſome fluid will be driven from the nearer part MN to the further part RS; and alſo ſome fluid will be driven from RS, through the canal, to the body D; ſo that the quantity of fluid in D will be increaſed thereby, and the quantity in A, taking the whole body together, will be diminiſhed; the quantity in the part near MN will alſo be diminiſhed; but whether the quantity in the part near RS will be diminiſhed or not, does not appear for certain; but probably it will be not much altered.

Cor.—In like manner, if B is made undercharged, ſome fluid will flow from D to A, and alſo from that part of A near RS, to the part near MN.

376 By crooked canals.

Suppoſe now that the bodies A and D communicate by the bent canal MPNnpm (fig. 109.) inſtead of the ſtraight one EF: let the bodies be either ſaturated or over or undercharged as before; and let the fluid be at reſt; then, if the body B is made overcharged, ſome fluid will ſtill run out of A into D; provided the repulſion of B on the fluid in the canal is not too great.

The repulſion of B on the fluid in the canal, will at firſt drive ſome fluid out of the leg MPpm into A, and out of NPpn into D, till the quantity of fluid in that part of the canal which is neareſt to B is ſo much diminiſhed, and its repulſion on the reſt of the fluid in the canal is ſo much diminiſhed alſo, as to compenſate the repulſion of B: but as the leg NPpn is longer than the other, the repulſion of B on the fluid in it will be greater; conſequently ſome fluid will run out of A into D, on the ſame principle that water is drawn out of a veſſel through a ſyphon: but if the repulſion of B on the fluid in the canal is ſo great as to drive all the fluid out of the ſpace GPHpG, ſo that the fluid in the leg MGpm does not join to that in NHpn; then it is plain that no fluid can run out of A into D; any more than water will run out of a veſſel through a ſyphon, if the height of the bend of the ſyphon above the water in the veſſel, is greater than that to which water will riſe *in vacuo*.

This is Mr Cavendiſh's reaſoning; but Dr Robiſon objects to it, that in theſe caſes the fluid does not move on the principle of a ſyphon, and that there is nothing to prevent the fluid from expanding in GPH. He was therefore of opinion, that it would always move from A to D over the bend.

Cor.—If AB is made undercharged, ſome fluid will run out of D into A; and that though the attraction of B on the fluid in the canal is ever ſo great.

377 Action of a plate on a ſtraight canal.

We ſhall now conſider the action of electrified bodies on the canal of communication, in ſome of the moſt important caſes. But, as we are confined in our limits, and have much important matter yet to treat of, we muſt content ourſelves, with enumerating facts without proving them by rigid demonſtration.

Let ACa, fig. 110. repreſent a thin conducting plate, ſeen edgwiſe, to the centre of which the ſlender canal CP is perpendicular. It is required to determine the action exerted by the fluid, or matter, uniformly diſpoſed over the plate, on the fluid moveable in PC?

1. To find the action of a particle at C on the fluid in the whole canal. Join AP, and let CP be denoted by x, AP by y, and AC by r. Alſo, let f repreſent the intenſity of action at the diſtance 1 of the ſcale from which the lines are meaſured.

The action of AmP is $\frac{f}{y^2}$, and it may be demonſtrated that the action of A on the whole of CP is $f\left(\frac{1}{r}-\frac{1}{y}\right)=f\left(\frac{y-r}{ry}\right)$.

2. To find the action of the plate whoſe diameter is Aa on a particle at P.

Let a denote the area of a circle whoſe diameter is $=1$. The action required will be expreſſed by the fluent $2fa\left(1-\frac{x}{y}\right)$.

Cor.—If PC be very ſmall in compariſon of AC, the action will be nearly the ſame as if the plate was infinite.

3. To find the action of the plate on the whole column. This will be expreſſed by the fluent $2fa$ $(x+r-y)$.

Our mathematical readers, who are familiar with the method of fluxions, (and to no others will theſe theorems be intelligible), will readily ſee the meaning of theſe expreſſions.

The following geometrical conſtruction will render the action of the plate for the whole column, or its parts, more familiar, and more eaſily remembered.

Produce PC till CK is = CA, and with the centre P, deſcribe the arch AI, croſſing CK in I. Then the electrical action will be expreſſed by $2fa \times \mathrm{IK}$; and this expreſſion repreſents a cylinder whoſe radius is 1 of the ſcale, and whoſe height is = 2 IK.

Again, about the centre p, with the diſtance pA, deſcribe the arch Ai, cutting CH in i. Then we have $2fa \times i\mathrm{K}$, expreſſing the action of the plate on the column Cp, and $fa \times \mathrm{I}i$, expreſſing its action on Pp.

By the formula $2fa \times \mathrm{IK}$, is meant, that the action exerted by the whole plate on PC is the ſame as if all the fluid in the cylinder expreſſed by $a \times 2\,\mathrm{IK}$ were placed at the diſtance from the acting particle denoted by 1.

378 Cor. 1.—If PC is very great compared with AC, the action is nearly the ſame as it would be if the column were infinitely extended.

379 Cor. 2.—If beſides, another column pC is very ſmall when compared with AC, the action on PC will be to that on pC, as pC to AC nearly.

The redundant fluid cannot be uniformly diffuſed over the whole plate, as we have hitherto ſuppoſed, ſince the mutual repulſion of its particles will render it denſer at the circumference. As it is difficult to determine the variation of denſity, we ſhall only ſtate the reſult of the extreme caſe, where the whole redundant fluid is crowded into the circumference of the plate.

380 The action of the fluid in the canal is now $fa\left(r - \frac{r^2}{y}\right)$, and the whole action of the fluid crowded into the circumference will be $far^2 \times \left(\frac{y-r}{ry}\right) = far\left(\frac{y-r}{y}\right)$. This may be thus repreſented geometrically. Deſcribe the quadrant CbBE, croſſing AP in B, and Ap in b. Draw BD and bd parallel to PC. Now, PB is $= y - r$, and DC$= r\left(\frac{y-r}{y}\right)$. The expreſſion $far\left(\frac{y-r}{y}\right)$ will therefore denote a cylinder whoſe radius is 1, and height DC, multiplied by f. Again dC will be the height of the cylinder expreſſing the action on pC, and Dd that of the cylinder expreſſing the action on Pp.

381 Cor. 1.—If CP be very great compared with CA, D is very near to A, and I to C, and CD has to IK very nearly the ratio of equality.

382 Cor. 2.—But if the column pC is very ſhort, the action of the fluid uniformly diffuſed over the plate, is to the action of the fluid crowded into the circumference nearly as 4AC to pC.

From this corollary we ſee that the receſs of the fluid towards the circumference, has a much leſs effect on ſhort columns than on *long* ones, i. e. the action in the former caſe will be much leſs diminiſhed. Any external force that tends to impel fluid along the canal, and from thence to diffuſe it over the plate, will impel a greater quantity to the plate when the fluid of the plate is crowded into the circumference, than if it were uniformly diffuſed over the plate, and this difference will be greater when the canal is ſhort.

383 Laſtly, When KL is equal to AP, or PL to KI, the repulſion exerted by the whole fluid of the plate, collected in K, on the fluid in the canal CL, is equal to the repulſion of the ſame fluid, when crowded into the circumference, on the column CP.

Cor. 1.—When CP is very long in compariſon with AC or KC, the actions of the two fluids in both the above ſituations is nearly equal.

Cor. 2.—The action exerted by the whole fluid on the column CP, when uniformly diffuſed, is to its action when collected in K, as 2 IK to CD.

384 Cor. 3.—If CNO be a ſpherical ſurface, or a ſpherical ſhell, of the ſame diameter and thickneſs with the plate Aa, and containing redundant fluid of uniform denſity, the action exerted by this fluid on the column CL is equal to twice the action of the fluid on the column CP, when the fluid is uniformly diffuſed over the plate, and to four times its action on the ſame column, when it is crowded into the circumference.

385 Action of two plates or ſpheres connected by infinite canals.

Let there be two circular plates, repreſented edgewiſe at DE, de, fig. 111. or two ſpherical ſhells ABO, abo, of the ſame diameters and thickneſs with the plates, containing redundant fluid of uniform denſity, and let them communicate with ſtraight canals OP, op, infinitely extended, perpendicular to their ſurfaces and paſſing through their centres, and let the fluid in theſe canals be of uniform denſity and equally diffuſed.

It may be demonſtrated that the repulſions exerted by the fluid in the plates or ſpheres on the canals are as the diameters of the plates or ſpheres.

386 Cor. 1.—When the canals are very long compared to the diameters of the ſpheres or plates, the repulſions are nearly in the ſame proportion.

387 Cor. 2.—The more the length of the canals diminiſhes when compared with the diameters of the plates or ſpheres, the more the repulſions approach to equality.

388 Cor. 3.—When the denſity of the fluid in two ſpherical ſhells is inverſely as their diameters, the repulſions of the contained fluid on a column of fluid infinitely extended, will be equal.

389 Cor. 4.—When the quantities of redundant fluid in two ſpheres are proportional to their diameters, the repulſions exerted by them on a canal infinitely extended are equal.

390 Cor. 5.—If there be two overcharged ſpheres, or ſpherical ſhells, as ABO, oab, fig. 112. that communicate by a conducting canal infinitely extended, the quantities of redundant fluid they contain are proportional to their diameters; and they will be nearly ſo if the canals be very long.

391 Cor. 6.—When the ſpheres of conducting matter are *in equilibrio*, the preſſures exerted by the fluid on their ſurfaces are nearly proportional to their diameters.

It follows from this corollary that the tendency of fluid to eſcape from ſuch ſpheres is, *cæteris paribus*, inverſely as the diameters.

392 Important caſe of four plates.

Let there be four circular plates, as HK, AB, DF, LM, fig. 113. equal and parallel to each other, and let two of them, AB and HK, communicate by an indefinite canal GC perpendicular to their planes and paſſing through their centres; let DF and LM communicate in like manner by the canal EN, both canals being in the ſame ſtraight line: let HK be overcharged, and LM juſt ſaturated. It is required to determine the diſpoſition of the fluid, and its proportion in the plates, ſo that the above condition may be poſſible and permanent, while all is *in equilibrio?*

As HK and AB communicate and are equal, as HK is overcharged, AB will be ſo alſo, and in the ſame degree, and the fluid will be ſimilarly diſpoſed in both. HK and AB being in this ſituation, if DF and LM be brought near them to within the diſtance CE, as in the figure, the redundant fluid in AB will act on the moveable fluid in DF, and force ſome of it along the canal EN into LM, rendering this latter overcharged. Now, if this redundant fluid in LM be taken off, the repulſion which LM was beginning to exert on the canal NE, will be diminiſhed or deſtroyed. Hence, more fluid will move from DF into LM, and this will again be overcharged. The redundant fluid in LM may again be taken off, but in leſs quantity than before, and ſo on repeatedly, till no more can be taken off. DF will thus be rendered undercharged, or will contain redundant *matter*. This will act on the fluid in GC, and attract it from G, and conſequently the fluid will now move from AK into AB, by which HK will be rendered leſs overcharged, and AB more ſo than at firſt. The thus increaſed redundancy of fluid in AB will act more ſtrongly on the moveable fluid in DF, and repel a part of it into LM as before. DF will thus be again rendered deficient, and by its redundant matter will again act on the canal GC. Thus, by repeatedly touching LM to take off the fluid driven into it from DF, or by allowing LM to communicate with conducting bodies, an equilibrium will be produced; and when this is the caſe, HK contains a certain quantity of redundant fluid, AB contains redundant fluid in a greater degree, DF contains redundant matter, and LM is in its natural ſtate. The problem may now be reduced to this. To find what proportion the redundant fluid in HK bears to that in AB, and what proportion this latter bears to the deficient fluid in DF?

To determine theſe proportions it is neceſſary that,

1ſt, The repulſion exerted by the redundant fluid in AB on the fluid in EN be preciſely equal to the attraction exerted by the redundant matter of DF on the ſame canal.

2dly, The repulſion exerted by the redundant fluid in HK on the whole fluid of the canal GC, balances the exceſs of the repulſion of the redundant fluid in AB on GC above the attraction of the redundant matter of DF on the ſame canal.

If we call the redundant fluid in AB, f; the redundant matter in DF, m; and the redundant fluid in HK, f': as the fluid in HK and AB is ſimilarly diſpoſed, (they being equal), and as it is probable that the redundant fluid in AB, and the redundant matter in DF, are ſimilarly diſpoſed, it follows, that their actions on the fluid in the canals will be ſimilar, and proportional to their quantities nearly.

Let 1 be to n, as the repulſion exerted by the fluid in AB on the fluid that would occupy CE, to the repulſion exerted by the fluid in AB on the fluid in EN or CG. AB acts on EN with the force $f\times(n-1)$; and DF acts on EN with the force $m\,n$; but theſe actions muſt balance each other, as LM is inactive. Therefore $f\times(n-1)=mn$, and $m=f\times\frac{(n-1)^2}{n}$.

If f repels the fluid in CG with the force fn, m attracts the fluid in CG with the force $m\times(n-1)$; but as $m=f\times\frac{(n-1)^2}{n}$, the attractive force of m for CG will be $f\times\frac{(n-1)^2}{n}\times(n-1)$: Therefore the repulſion of f is to the attraction of m, as fn to $f\times\frac{(n-1)^2}{n}$ $=fn^2:f\times(n-1)^2=n^2:n-1^2$.

Let r denote the repulſion of f, and a the attraction of m; then $r:a=n^2:(n-1)^2$; and $r:(r-a)=n^2:n^2-(n-1)^2=n^2:(2n-1)$.

But the repulſion of $f'=r-a$; therefore $n^2:(2n-1)=f:f'$, and $f'=f\times\left(\frac{2n-1}{n^2}\right)$; or $f=f'\times\left(\frac{n^2}{2n-1}\right)$.

If we ſuppoſe n^2 much greater than $2n-1$, we ſhall have the quantity of redundant fluid in AB much greater than that in HK.

393 Prodigious accumulation and diſſipation of redundant fluid,

When EC is very ſmall in proportion to AC, it will appear, on referring back to N° 382. that 1 is to n nearly as CE : CA; and conſequently $n=\frac{AC}{CE}$ nearly. When this is the caſe, n is a conſiderable quantity; and there is ſo little difference between $\frac{n^2}{2n}$ and $\frac{n^2}{2n-1}$, that we may take the former for the latter without any material error. Now we have $f=f'\times\frac{n}{2}$ very nearly. Suppoſe AC to repreſent 6 inches, and CE $\frac{1}{10}$th of an inch, we ſhall have $n=12a$ and $f=60f'$, or more exactly $f'=\left(\frac{n^2}{2n-1},=\frac{14{,}400}{239}=\right)60\frac{1}{4}$.

This, it will be remembered, repreſents the redundant fluid in HK; hence it will appear how great muſt be the redundancy in HK.

Again, when AB and DF are very near, n is a large number, and the deficiency in DF is nearly equal to the redundancy in AB. In the above example m is $\frac{59}{60}$ths of f', as $m=f\times(n-1)$.

But though there is this great deficiency in DF, and redundancy in AB, DF is not electrical on the ſide next LM, nor is AB more electrical than HK; in ſhort, this caſe affords another example of bodies being neutral while redundant or deficient, in addition to what was advanced in N° 313, 314.

394 without any ſenſible electrical effect.

It will readily occur to the reader, that caſes exactly ſuch as we have now ſtated never happen in the courſe of experiment; but when the canals are very long in compariſon of the diameters of the plate, and when AB is very near DF, the proportions will not greatly vary.

395 Mode of reſtoring the equilibrium by degrees:

We have been very particular in the examination of this caſe, becauſe it is of great importance, and will aſſiſt us in explaining ſome of the principal phenomena. To prepare for ſuch an application of it, we ſhall here ſtate ſome ſimple conſequences of this combination of plates.

If AB be touched by any body, this body will receive from it a part of its redundant fluid, but only a part; for only ſo much fluid will quit AB as is ſufficient to render it neutral, while the touching body communicates with the ground. This will happen till the redundant matter in DF attracts fluid on the remote ſide of AB as much as the redundant fluid in AB repels it. The repulſion of AB on EN is now diminiſhed, the attraction of DF will therefore prevail, and this will be no longer neutral. If now DF be touched, it may again be made neutral with reſpect to EN; but AB will again repel the fluid in CG, and being redundant on that ſide will again become electric. AB being touched again, loſes more fluid, and DF becomes electric by deficiency. Thus by alternately touching AB and DF, the redundancy in AB may be exhauſted, and the deficiency in DF ſupplied.

396 At once. But the equilibrium that is thus *gradually* produced may be effected at once. If we ſuppoſe a ſlender conducting canal *a b d*, brought very near the plates on the outſide, ſo that the end *a* is near to A, and *d* to D; the firſt effect of the vicinity of *a* to A, will be to cauſe the fluid in *a b* to recede a little from *a*, by reaſon of the repulſion of the redundant fluid in AB. Thus, redundant matter will be left at *a*, and this will ſtrongly attract redundant fluid from A, and *a* may receive a ſpark. Should the fluid approach ſtill nearer the ſurface at A, the correſponding part of DF will be rendered more attractive, and by the fluid retiring from *a* along *a b*, ſome of the natural fluid of this canal will be puſhed towards *d*; this increaſes the diſpoſition of A to part with fluid, and of *d* to receive it, while *a* is diſpoſed to give out and D to receive. Thus all contributes to favour the paſſage of almoſt the whole of the redundant fluid in AB to ruſh from AB, by A, along *a b d* into DF.

It is alſo clear that, without the canal *a b d*, there is a ſtrong tendency of the fluid in AB for the matter in DF, and that, of courſe, theſe plates will ſtrongly attract each other.

The theorems we have now given reſpecting the diſpoſition of the electric fluid are the reſult of mathematical reaſoning, founded on the hypothetical nature of the fluid, and its aſſumed law of action. We ſhall conclude this ſection with relating the reſult of M. Coulomb's experiments on this ſubject, given in the Memoirs of the Academy for 1786 and 1787. M. Coulomb gives the following general theorem.

397 Coulomb's experiments on the denſity of the fluid in contact. In a body of any form, AFB*de*, fig. 114. which is ſuppoſed filled with fluid whoſe particles act on each other with a force that is inverſely as the ſquare of the diſtance, let there be raiſed a perpendicular *a b* infinitely ſmall, and let a plane, perpendicular to *a b* at the point *b*, divide the body into two parts; one *d a c b*, infinitely ſmall, the other *b* AFB *c b*, of any determinate dimenſions. Then the action of the particles compoſing the thin ſlice, eſtimated in the direction *a b*, on the particle *b*, muſt be equal to the action of the whole fluid in the reſt of the body, if *b* be ſuppoſed at reſt. Now, as whatever be the diſpoſition of the fluid, the law of continuity will be the ſame, it is evident that if we take *a b* ſufficiently ſmall, the difference of the denſity at *a* and at *c* may be infinitely ſmall; and that the action of *dcbe* will be infinitely near to an equilibrium with that of *da eb*. Hence the action of the fluid in the reſt of the body will be reduced to nothing, or will be infinitely ſmall. But this cannot take place when the action of the maſs at a finite diſtance on a particle of fluid, is infinitely ſmall with reſpect to that of a particle in contact on the ſame particle, unleſs we ſuppoſe the quantity of fluid at a finite diſtance nearly nothing. It follows that the whole redundant fluid muſt be conſtipated on the ſurface, and the interior parts be merely ſaturated.

M. Coulomb then proceeds to examine the denſity of the electric fluid in different bodies that are in contact.

He firſt examines the denſity of two globes of different diameters in contact.

After a number of experiments, he gives the reſult in the following table, repreſenting the manner in which the fluid is diſtributed between the two globes. The firſt column ſhews the proportion of the radii of the globes, the ſecond the proportion of their ſurfaces, and the third the correſponding proportion of their denſities. It muſt be remarked that this table ſhews only the proportional denſity of the globes, when after being ſeparated, the fluid is uniformly diffuſed over their ſurfaces.

1	1	1
2	4	1,08
4	16	1,30
8	64	1,65
infinite	infinite	2,00

Thus it appears, that the greater the proportion of the ſurfaces of the globes, the nearer the proportion of their denſities approached to 2, but never attained this.

This is very different from the proportions between two ſpheres that communicate by a very long ſlender canal, which, as was ſhewn in N° 390, contained quantities of fluid proportional to their diameters, and that the denſities were inverſely as the diameters; and this M. Coulomb found to agree very exactly with experiment.

M. Coulomb nexts proceeds to examine the denſity of the fluid in various parts of the ſurface of the globes in contact, in order to aſcertain the diſtribution.

His method of proceeding was this. He hung a ſmall circle of gilt paper to a thread of lac, fixed to a cylinder of glaſs or baked wood; the paper was varniſhed with ſome electric ſubſtance. The body to be examined was firſt touched with the paper circle, the electricity of which was then examined by means of his electrometer, and an eſtimation of the denſity of the ſpheres made on the ſuppoſition that the circle brought off one half of the electricity of the touched point.

The reſult of numerous experiments made with two globes in contact was as follows. The more unequal the globes were, the more the denſity of the ſmall globe varied from the point of contact to the diſtance of 180°, and the nearer it approached to uniformity in the large globe, increaſing rapidly from the point of contact, where it was 0, to 7° or 8° from that point. Thus, when he placed a ſphere of 8 inches in contact with one of two inches, he found the denſity of the ſmall globe inſenſible till about 30° from the point of contact; that at 45° it was nearly the one-fourth of what it was at 90°, and hence it increaſed in the proportion

of

of 10 to 14 till 180°, where it was uniform. In the larger globe, on the other hand, the denſity was 0 till about 4° or 5°; hence it increaſed rapidly, and from 30° to 180° it was nearly uniform.

From theſe reſults we may conclude that Mr Cavendiſh's mathematical demonſtration of the uniform diſtribution of the fluid in a globe that communicates with another by a ſlender canal, is conformable to the fact.

A ſmall globe between two equal larger globes, was found to poſſeſs the ſame electricity as the other two, when the proportion of their radii was not more than 5 to 1; when it was greater, the ſmall globe ſhewed no electricity.

Three equal globes being placed in contact, the denſity in the middle one was $\frac{1}{1,34}$ of that in the other two. When a ſmall globe, after having been in contact with a larger one that was overcharged, was removed to a very ſmall diſtance, the electricity of the ſmall globe in the fronting point was oppoſite to that of the large one, at a little greater diſtance the ſmall globe was neutral, and ſtill farther off, it was redundant.

When the diameters of the globes were 11 and 8 reſpectively, the ſmall globe at the fronting point was negative, till it was at the diſtance 1, when it was neutral, and beyond this it was poſitive. When the diameters were 11 and 4, the neutral diſtance was 2, and when they were 11 and 2, the diſtance at which the ſmall globe was neutral was $2\frac{1}{2}$.

It is indifferent whether the globes be ſolid, or conſiſt merely of a thin ſhell. This circumſtance is an additional proof of the juſtneſs of the theoretical inveſtigation, on the ſuppoſition of the fluid being diffuſed over the ſurface, leaving the interior parts in a neutral ſtate.

SECT. II. *An Application of the Theory of Æpinus and Cavendiſh to the principal Phenomena of Electricity.*

398 On an attentive conſideration of the phenomena that have already paſſed under our review, and a careful compariſon of theſe with the theory of poſitive and negative electricity, as improved by Æpinus and Cavendiſh, it will, we think, appear, that this theory is adequate to the explanation of the facts.

The compariſon of the theory with the experiments may readily be made, and we have already hinted at it in ſeveral caſes. We cannot, however, purſue this to any extent, and muſt reſtrict ourſelves in the remainder of this chapter to the more important and intereſting phenomena, leaving the reſt to be ſupplied by the reader, for which purpoſe we have furniſhed him with ample materials.

We have already, in our illuſtration of the theory of Æpinus, ſo fully conſidered the phenomena of electric attraction and repulſion in a general view, that little more needs to be done, than to explain a few of the more remarkable caſes.

The phenomena of attraction and repulſion may be reduced to the following ſimple propoſitions.

399 Electricity by poſition illuſtrated.

PROP. I.—If any body be electrified by any means, and if another body be brought near it, this latter becomes electrified by poſition.

We ſhall illuſtrate this propoſition by the following ſimple experiment.

Let there be provided three metallic conductors, each ſupported on an inſulating ſtand, ſuch as A, B, C, fig. 115. Set theſe in a row, with their extremities touching each other, and at one end of the row, as at *c*, place a ſtand, to which is hung a ball electrometer with ſilk threads. On bringing an excited electric near *a*, the oppoſite end of the conductor, the pith ball will approach the end *c*. Care muſt, however, be taken not to bring the electric ſo near *a*, as to make the ball ſtrike the oppoſite extremity; as in that caſe the experiment would come under our ſecond propoſition. When the excited electric is removed, the ball retires to its perpendicular ſituation. The ſame effect will be produced if the electrometer be placed at the ſide of the conductor, inſtead of its extremity, clearly ſhewing that it is affected by the conductor, and not immediately by the excited electric.

This is an inſtance of induced electricity, and is eaſily explained on the principles mentioned in N° 344. The approach of the excited electric to the end *a* of the compound conductor, renders this end deficient, if the electric be overcharged, or redundant if it be undercharged; and the oppoſite extremity is in the contrary ſtate, and hence attracts the ball of the electrometer.

Although the oppoſite extremities of the conductor are in oppoſite ſtates, the fluid is variouſly diſpoſed in various parts of the conductor; as may be proved in the following manner. While the excited electric remains near *a*, take away the two extreme conductors, A and C, or, if only two have been employed, take away the remote one; remove the excited electric, and examine the parts of the conductor ſeparately. The part A will be found entirely negative; if the electric were overcharged, C will be entirely poſitive; and if three pieces have been employed, the middle piece B will be faintly poſitive. If the pieces be again united, they will be found devoid of electricity. The ſame appearances will be more completely ſeen by forming a conductor of a ſeries of metallic balls, ſuſpended by ſilk threads, one of which will be found ſcarcely electrical.

PROP. II.—When an inſulated body is brought very near an electrified body, a ſpark paſſes between them, and the inſulated body becomes electrified permanently by communication, while the electricity of the electrified body is diminiſhed. 400

In this caſe the electricity imparted is of the ſame kind as that of the electrified body, poſitive if this were poſitive, and *vice verſa*. The propoſition may be illuſtrated by the ſame apparatus of the conductors and electrometers, and ſcarcely requires an explanation.

When the electricity is in a ſmall degree, the ſpark is either very ſmall or ſcarcely perceptible, but there is no doubt, that it takes place in all caſes. The ſpark is owing to the ſudden transference of a portion of the fluid from the electrified body to the unelectrified body.

401 Repulſion of bodies in the ſame ſtate.

PROP. III.—When an electrified body has communicated part of its electricity to another body, this latter is repelled, unleſs it has communicated its acquired ſtore to other bodies.

The flying feather, the cork balls, and many other experiments related in the firſt chapter of Part III. amply

amply illuſtrate this propoſition, which expreſſes one of the moſt general facts in electricity.

Before the electrified body has communicated part of its electricity to the body preſented to it, this latter is in its natural ſtate; but after the communication, both are either redundant or deficient, and conſequently repel each other, as appears from N° 323, 324.

From theſe general propoſitions we may deduce the following corollaries, an application of which will ſerve ſtill further to illuſtrate and explain the phenomena of electric attraction and repulſion.

402 Cor. 1.—The vivacity of the appearances produced by a transference of fluid will be proportional to the quantity of fluid transferred.

403 Cor. 2.—The phenomena of communicated electricity will be more remarkable, the greater the conducting power of the bodies to which it is communicated.

It will have appeared from numerous experiments related in Part III. eſpecially that of the *dancing balls* in N°94. that an imperfect conductor, ſuch as glaſs, permits the communication of electricity only in the point preſented to an electrified body; whereas, when electricity is communicated to one point of a tolerably perfect conductor, ſuch as the prime conductor of a machine, the whole conductor is inſtantly pervaded, and becomes electrical in every part.

404 Cor. 3.—When an electrified body has a free communication with a perfect conductor, its electricity cannot apparently be communicated to a body touched by it.

For the maſs of the earth, with which the body communicates, bears ſo great a proportion to the body itſelf, that when the electricity of the latter is communicated to the former, it becomes imperceptible in both.

405 Cor. 4.—When an unelectrified body is preſented to an electrified body, the former is firſt attracted, comes in contact with the electrified body, and is then repelled.

This corollary has been illuſtrated by numerous experiments; we may inſtance the *dancing figures*, &c. and the appearances are eaſily explained. The unelectrified body becomes electrical by induction; in conſequence of this, it is attracted to the electrified body, from which it receives a ſpark, becomes electrified by communication, and being now in the ſame ſtate with the electrified body, is repelled by it.

It will probably have been obſerved, in making the experiment of preſenting a feather, or a pith ball, ſuſpended by a ſtring to the prime conductor, that they cling to the conductor, and are not repelled for ſome time. The reaſon of this is, that theſe bodies are imperfect conductors, eſpecially when very dry, and hence their ſurface is not eaſily pervaded by the fluid; when this becomes equally diffuſed, they are repelled. The ſame circumſtance explains why the balls of the common electrometer ſometimes adhere together, and then ſeparate with a jerk.

406 Cor. 5.—Electrical attraction and repulſion are not prevented by the interpoſition of unelectrified non-conducting ſubſtances.

A thin plate of glaſs may be interpoſed between the conductor and the pith-ball in the experiment of N° 399, and ſtill, though the plate be very extenſive, the electrometer will be affected.

Nay, an inſulated electrified body may be covered with a glaſs bell, and it will yet attract a ball preſented to it.

407 Hypotheſis of electric atmoſpheres.

As this ſingle circumſtance affords one of the beſt arguments againſt the hypotheſis of material electric atmoſpheres, which has been maintained, and is ſtill maintained, by ſome of our moſt eminent electricians; we ſhall take this opportunity of giving a brief account of this hypotheſis, and ſtating the reaſons which induce us to reject it.

It has been ſuppoſed, that the electric fluid is collected around the ſurface of an electrified body, forming a kind of atmoſphere; and that on theſe atmoſpheres depended the action of theſe electrified bodies. If the reader will examine the plates of Lord Stanhope's *Principles of Electricity*, he will ſee the figures of conductors ſurrounded with a ſhining margin, like the line of coaſts and iſlands in a map.

This idea of electric atmoſpheres was firſt held at a very early period of the ſcience by Otto Guericke, and afterwards by the academicians del Cimento, who contrived to render the electric atmoſphere viſible, by means of ſmoke attracted by, and uniting itſelf to a piece of amber, and gently riſing from it, and vaniſhing as the amber cooled. But Dr Franklin exhibited this electric atmoſphere with great advantage, by dropping roſin on hot iron plates held under bodies electrified, from which the ſmoke roſe and encompaſſed the bodies, giving them a very beautiful appearance. He made other obſervations on thoſe atmoſpheres: he took notice that they and the air did not ſeem to exclude one another; that they were immoveably retained by the bodies from which they iſſued; and that the ſame body, in different circumſtances of dilatation and contraction, is capable of receiving and retaining more or leſs of the electric fluid on its ſurface. However, the theory of electrical atmoſpheres was not ſufficiently explained and underſtood for a conſiderable time; and the inveſtigation led to many very curious experiments and obſervations. Mr Canton took the lead, and was followed by Dr Franklin. Meſſrs Wilcke and Æpinus proſecuted the inquiry, and completed the diſcovery. The experiments of the two former gentlemen prepared the way for the concluſion that was afterwards drawn from them by the latter, though they retained the common opinion of electric atmoſpheres, and endeavoured to explain the phenomena by it. The concluſion was, that the electric fluid, when there is a redundancy of it in any body, repels the electric fluid in any other body, when they are brought within the ſphere of each others influence, and drives it into the remote parts of the body, or quite out of it, if there be any outlet for that purpoſe.

By atmoſphere M. Æpinus ſays, no more is to be underſtood than the ſphere of action belonging to any body, or the neighbouring air electrified by it. Sig. Beccaria concurs in the ſame opinion, that the electrified bodies have no other atmoſphere than the electricity communicated to the neighbouring air, and not with the electrified bodies. And Mr Canton likewiſe, having relinquiſhed the opinion that electrical atmoſpheres were compoſed of effluvia from excited or electrified bodies, maintained that they only reſult from an alteration in the ſtate of the electric fluid contained in, or belonging to the air ſurrounding theſe bodies to a certain diſtance; for inſtance, that excited glaſs repels the electric fluid from it, and conſequently beyond that diſtance makes

makes it more denſe; whereas excited wax attracts the electric fluid exiſting in the air nearer to it, making it rarer than it was before.

Among the ſupporters of this doctrine is Dr Peart of Gainſborough, who has diſtinguiſhed himſelf as a zealous opponent of the chemical theory of Lavoiſier, the fallacy of which he has, in his own opinion, fully demonſtrated. Bur Dr Peart's atmoſpheres are not thoſe of moſt electricians; they conſiſt of chemical elements, of *ether* and *phlogiſton*, by the union and reciprocal action of which all the phenomena of electricity are effected. We are afraid of doing more than ſtating this leading principle of Dr Peart's hypotheſis, leſt we ſhould ſhare the fate of Mr Read, with whom the Doctor is very angry for only partially agreeing with him.

We muſt therefore refer ſuch of our readers, as wiſh for more ſatisfaction on this head to the Doctor's pamphlets on *electricity and magnetiſm*, and on *electric atmoſpheres*.

408 Refuted.

It is perhaps a ſufficient refutation of this doctrine of material atmoſpheres, that electrical attraction and repulſion may take place, where theſe atmoſpheres cannot, according to the general opinion, be formed. Thus, in the inſtance given above, it is ſcarcely conceivable, that the excited electric on one ſide of the glaſs pane, or bell, ſhould ſo ſpeedily extend its atmoſphere to the other ſide of the pane, or, in the caſe of the bell, that it ſhould extend it at all, ſo as inſtantaneouſly to affect an electrometer preſented to the other ſide. Nay, it is well known, that an electrified body will affect a conducting wire, ſo as to render it poſitive at one end, and negative at the other, though the wire be completely enveloped in ſealing-wax, or ſome other electric ſubſtance. It therefore becomes a queſtion, how, if the interpoſed body be impermeable to the electric fluid, (and we ſee no reaſon to think that glaſs and other perfect electrics are not ſo), the electric atmoſphere can be produced? The one atmoſphere can, in this inſtance, produce the other only by acting at a diſtance on the particles of which this latter is to be formed. Even ſuppoſing that the one atmoſphere could produce the other in this way, we ſhould gain nothing by the ſuppoſition. It only ſuppoſes innumerable attractions and repulſions in place of one.

Dr Franklin whirled an electrified ball, ſuſpended by a ſilk thread, many times about his head with great rapidity, and found that its electricity was not ſenſibly diminiſhed by the motion. Now it is ſcarcely conceivable, that the electric atmoſphere could remain attached to the ball under theſe circumſtances, or that it could be ſo inſtantaneouſly formed, or renewed in every point of its revolution, as to be capable of acting the moment the motions were ended; for the electricity of the ball muſt in this way have been greatly leſſened, or nearly exhauſted; whereas Dr Franklin found that, when the air was very dry, the electricity of the revolving ball was, when the ball was ſtopped, not leſs than that of a ſimilar ball that had remained for the ſame time in a ſtate of reſt.

409 Permeability of glaſs ſuppoſed by ſome.

We have ſaid that we ſee no reaſon to think, that glaſs is permeable to the electric fluid. We are aware, that this permeability is ſupported by ſome electricians, and that experiments have been related in proof of their opinion. Among the moſt plauſible of theſe, are the experiments of Mr Lyons of Dover, which may all be reduced to the following. 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 end of the glaſs, oppoſite to the pointed wire. With this apparatus he obtains a diſcharge, and therefore ſays that the glaſs is permeable to the electric fluid.

Dr Robiſon repeated moſt of Mr Lyons's experiments, and found that, in the above way, he did indeed procure diſcharges, but that theſe were very incomplete, and very unlike the full and audible diſcharge uſually obtained; they were always very faint, except when the glaſs was perforated.

410 Electrics only ſo ſuperficially.

To terminate this long digreſſion, it muſt be remarked, that the impermeability of electrics ſuppoſed in our theory, ſhews that the redundancy or deficiency induced in an overcharged or undercharged electric, does not extend beyond the ſurface; for, when the ſurface is rendered electrical by excitation in any way, the impermeability of the body prevents the redundant fluid from penetrating to any depth, or from expanding to ſupply the deficiency on the ſurface. Hence we find, that an excited electric, when plunged into water, quickly loſes its electricity by communication with this conducting medium.

We muſt now return to our corollaries, of which we ſhall deduce one more.

411 Compenſated electricity.

Cor. 6.—As non-electrics are conductors, and as ſome electrics are excited by rubbing them with non-electrics, it will follow, that if the non-electrics be inſulated and ſeparated from the electric, the former will ſhow ſigns of electricity as well as the latter, but that, while they remain together, no ſigns of electricity can be exhibited by either.

This corollary may be illuſtrated by numerous facts that have been related in the preceding parts of this article.

The ſheets of paper in N° 19. ſhowed no ſigns of electricity while in contact with the table; the ſulphur in the experiments of Wilcke and Æpinus, was not electrical while within the metallic cups, &c.

When caſes of this kind occur, in which two bodies, that would, when ſeparated after mutual contact, ſhow ſigns of oppoſite electricities, are, when united, ſaid to *compenſate* each other, the circumſtance is eaſily explained.

In whatever way excitation is produced by friction or other means, which we do not pretend to explain, it muſt happen that the adjoining ſurfaces of two bodies rubbed together, muſt be in oppoſite ſtates, and the one overcharged in the ſame degree as the other is undercharged. When the bodies, which we ſhall ſuppoſe to be two plates, are joined, ſo that the one exactly covers the other, they muſt be inactive; becauſe a particle of moveable fluid in any part of one ſurface of the overcharged plate, will be as much attracted by the undercharged ſurface of the farther plate, as it is repelled by the overcharged ſurface of the nearer plate. As the ſurfaces are ſuppoſed equal, coincident, and equally electrical, their actions muſt balance each other. The action of the united bodies will be expreſſed by $F'm' \times (z-z')$ or $F'm'$; $z-z'$ being here $=0$.

But now again, if the plates be ſeparated, a conſiderable part of the redundant fluid will fly back from the one ſurface to the other, being impelled thither by the repulſion of its own particles, and drawn by the attraction of the redundant matter in the other ſurface. But, as the electric is a non-conductor, it will retain a portion of fluid, or will remain deprived of a portion, in a ſtratum a little way within the ſurface, the two plates muſt, after ſeparation, be in oppoſite ſtates, and the non-electric plate, if it has been inſulated before ſeparation, will, after ſeparation, appear electrified.

We ſhall cloſe our conſideration of electrical attraction and repulſion, by explaining two very beautiful experiments of Dr Franklin; one of which, the electrical well, has been deſcribed in N° 79; the other ſhall be deſcribed preſently.

412 Electrical well explained.

It appears from Mr Cavendiſh's account of the diſpoſition of fluid in a ſphere, given in N° 372, that when the ſphere is overcharged, all the redundant fluid is crowded into the ſurface, leaving the internal parts in a neutral ſtate. Now the veſſel that repreſents the electrical well is exactly in this condition; the electrometer, therefore, when let down within the cavity of the veſſel, cannot be affected, becauſe all that ſpace is neutral; but when the balls are raiſed above the brim of the veſſel, they are affected, becauſe they come within the ſphere of action of the redundant ſurface.

The other experiment to which we allude, is that of the electrified can and chain, which is thus made.

413 Electrified can and chain.

Inſulate a metallic can, or any other concave piece of metal, and place within it a pretty long metallic chain, having a ſilk thread tied to one of its ends. At the handle of the can, or to a wire proceeding from it, ſuſpend a cork ball electrometer; then electrify the can, by giving it a ſpark with the knob of a charged phial, and the balls of the electrometer will immediately diverge. If, in this ſituation, one end of the chain be gradually raiſed up above the top of the can, by the ſilk thread, while the lower end of the chain remains in it, the balls of the electrometer will converge a little, and more or leſs in proportion to the greater or leſs elevation of the chain above the top of the veſſel. A ſimilar experiment was made by Mr Ronayne, which is as follows:—He excited a long ſlip of white flannel, or a ſilk ribband, by rubbing it with his fingers; then, by applying his hand to it, took off as many ſparks as the excited electric would give; but when the flannel, &c. had loſt the power of giving any more ſparks in this manner, he doubled, or rolled it up; by which operation the contracted flannel, &c. appeared ſo ſtrongly electrical, that it not only afforded ſparks to the hand, brought near, but it threw out ſpontaneous bruſhes of light, which appeared very beautiful in the dark.

To explain this experiment, we muſt have recourſe to an inference, that is eaſily deducible from the ſame theorem of Mr Cavendiſh: namely that in overcharged bodies of all ſhapes, the redundant fluid will be much more denſe near the ſurface than in the more internal parts; and that it will be alſo denſer in all elevated or protuberant parts of theſe bodies, as alſo near the extremity of oblong bodies; and in general, that the redundant fluid, or redundant matter, will bear a much nearer proportion to the ſurfaces of bodies, than to their quantities of matter. Hence we may perceive, that when the chain, in the above experiment, is lifted up, it will attract to itſelf a part of the denſer fluid, leaving that of the ſurface of the veſſel, to which the electrometer is attached, more rare; and conſequently, the divergence of the balls will decreaſe, in proportion as the chain is more elevated above the rim of the cup. Mr Ronayne's experiment admits of a ſimilar explanation.

414 Action of points explained.

The well known effects of points, in cauſing a quick diſcharge of electricity, ſeem to agree very well with this theory.

It appears from 391, that, if two ſimilar bodies of different ſizes are placed at a very great diſtance from each other, and connected by a ſlender canal, and overcharged, the force with which a particle of fluid placed cloſe to correſponding parts of their ſurface is repelled from them, is inverſely as the correſponding diameters of the bodies. If the diſtance of the bodies is ſmall, there is not ſo much difference in the force with which the particle is repelled by the two bodies; but ſtill, if the diameters of the two bodies are very different, the particle will be repelled with much more force from the ſmaller body than from the larger. It is indeed true, that a particle placed at a certain diſtance from the ſmaller body, will be repelled with leſs force, than if it be placed at the ſame diſtance from the greater body; but this diſtance is in moſt caſes pretty conſiderable. If the bodies are ſpherical, and the repulſion inverſely as the ſquare of the diſtance, a particle placed at any diſtance from the ſurface of the ſmaller body, leſs than a mean proportion between the radii of the two bodies, will be repelled from it with more force than if it be placed at the ſame diſtance from the larger body.

We may probably, therefore, be well aſſured, that if two ſimilar bodies are connected together by a ſlender canal, and are overcharged, the fluid muſt eſcape faſter from the ſmaller body than from an equal ſurface of the larger; but as the ſurface of the larger body is greateſt, it is not certain which body ought to loſe moſt electricity in the ſame time; and indeed it ſeems impoſſible to determine poſitively from this theory which ſhould, as it depends in a great meaſure on the manner in which the air oppoſes the entrance of the electric fluid into it. Perhaps, in ſome degrees of electrification, the ſmaller body may loſe moſt, and in others the larger.

Let now ACB (fig. 116.) be a conical point, ſtanding on any body DAB, C being the vertex of the cone; and let DAB be overcharged: Mr Cavendiſh ſuppoſes, that a particle of fluid placed cloſe to the ſurface of the cone anywhere between *b* and C, muſt be repelled with at leaſt as much, if not more, force, than it would, if the part A *a* *b* B of the cone was taken away, and the part *a* C *b* connected to DAB by a ſlender canal; and conſequently, from what has been ſaid before, it ſeems reaſonable to ſuppoſe that the waſte of electricity from the end of the cone muſt be very great in proportion to its ſurface; though it does not appear from this reaſoning, whether the waſte of electricity from the whole cone ſhould be greater or leſs than from a cylinder of the ſame baſe and altitude.

All that has been here ſaid relating to the flowing out of of electricity from overcharged bodies, holds equally true with regard to the flowing in of electricity into undercharged bodies.

But a circumſtance which probably contributes as much as any thing to the quick diſcharge of electricity from points, is the ſwift current of air cauſed by them, as taken notice of in N° 80 *et. ſeq.* and which is produced in this manner.

If a globular body ABD is overcharged, the air cloſe to it, all round its ſurface, is rendered overcharged by the electric fluid, which flows into it from the body; it will therefore be repelled by the body; but as the air all round the body is repelled with the ſame force, it is in equilibrio, and has no tendency to fly off from it. If now the conical point ACB be made to ſtand out from the globe, as the fluid will eſcape much faſter in proportion to the ſurface from the end of the point than from the reſt of the body, the air cloſe to it will be much more overcharged than that cloſe to the reſt of the body: it will therefore be repelled with much more force; and conſequently a current of air will flow along the ſides of the cone from B towards C; by which means there is a continual ſupply of freſh air, not much overcharged, that the electricity would have but little diſpoſition to flow from the point into it.

The ſame current of air is produced in a leſs degree, without the help of the point, if the body, inſtead of being globular, is oblong or flat, or has knobs on it, or is otherwiſe formed in ſuch a manner as to make the electricity eſcape faſter from ſome parts of it than the reſt.

In like manner, if the body ABD be undercharged, the air adjoining to it will alſo be undercharged, and will therefore be repelled by it; but as the air cloſe to the end of the point will be more undercharged than that cloſe to the reſt of the body, it will be repelled with much more force; which will cauſe exactly the ſame current of air, flowing the ſame way, as if the body was overcharged; and conſequently the velocity with which the electric fluid flows into the body, will be very much increaſed. We believe, indeed, that it may be laid down as a conſtant rule, that the faſter the electric fluid eſcapes from any body when overcharged, the faſter will it run into that body when undercharged.

Points are not the only bodies which cauſe a quick diſcharge of electricity; in particular, it eſcapes very faſt from the ends of long ſlender cylinders; and a ſwift current of air is cauſed to flow from the middle of the cylinder towards the end: this will eaſily appear by conſidering, that the redundant fluid is collected in much greater quantity near the ends of the cylinders than near the middle. The ſame thing may be ſaid, but we believe in a leſs degree, of the edges of thin plates.

What has been juſt ſaid concerning the current of air, ſerves to explain the reaſon of the revolving motion of Dr Hamilton's and Mr Kinnerſley's bent pointed wires, (N° 81.) for the ſame repulſion which impels the air from the thick part of the wire towards the point, tends to impel the wire in the contrary direction.

It is well known, that if a body B is poſitively electrified, and another body A, communicating with the ground, be then brought near it, the electric fluid will eſcape faſter from B, at that part of it which is turned toward A, than before. This is plainly conformable to theory; for as A is thereby rendered undercharged, B will in its turn be made more overcharged, in that part of it which is turned towards A, than it was before. But it is alſo well known, that the fluid will eſcape faſter from B, if A be pointed, than if it be blunt, though B will be leſs overcharged in this caſe than in the other; for the broader the ſurface of A, which is turned towards B, the more effect will it have in increaſing the overcharge of B. The cauſe of this phenomenon is as follows.

If A is pointed, and the pointed end turned towards B, the air cloſe to the point will be very much undercharged, and therefore will be ſtrongly repelled by A, and attracted by B, which will cauſe a ſwift current of air to flow from it towards B; by which means a conſtant ſupply of undercharged air will be brought in contact with B, which will accelerate the diſcharge of electricity from it in a very great degree; and moreover, the more pointed A is, the ſwifter will be this current. If, on the other hand, that end of A which is turned towards B is ſo blunt, that the electricity is not diſpoſed to run into A faſter than it is to run out of B, the air adjoining to B may be as much overcharged as that adjoining to A is undercharged; and, therefore may, by the joint repulſion of B and attraction of A, be impelled from B to A, with as much, or more force, than the adjoining air to A is impelled in the contrary direction; ſo that what little current of air there is, may flow in the contrary direction.

We might here give an account of Coulomb's experiments on the diſſipation of electricity into the air, and along imperfect conductors. But we muſt defer this to the article ELECTROMETER, under which we ſhall deſcribe the inſtrument with which they were made. We muſt now proceed to the theory of the Leyden phial.

415
Phenomena of charged glaſs illuſtrated.

In the 4th, 6th, and 7th chapters of the third part, we have related a conſiderable number of experiments, illuſtrating the phenomena of charged electrics. Before we examine the theory of the Leyden phial, it will, therefore, be neceſſary to conſider the phenomena only in a ſimple caſe, and for this purpoſe we ſhall give an experiment, by which the late Dr Robiſon uſed to illuſtrate the theory of charged glaſs.

Fig. 117. repreſents the profeſſor's apparatus. G is the extremity of a prime conductor, on which is fixed a quadrant electrometer H. AB repreſents a round plate of tin-foil, paſted on a plate of glaſs, the edges of which extend beyond the tin-foil about two inches. The plate of glaſs is fixed to a wooden ſtand, ſo that it may be placed upright, and at any required diſtance from the conductor. DF is another plate of equal dimenſions with AB, having a wire EN fixed in its centre, with its extremity N, terminating in a ſmall ball, from which is hung a common ball electrometer. The wire alſo paſſes through a wooden ball O, which is faſtened to the inſulating ſtand P. It is neceſſary that the glaſs plates be very clean and dry, and a little warm.

The conductor G is to be connected with the plate AB, by a wire reaching to the centre C. Now move the electrical machine ſlowly, till the index of the quadrant riſe to 30° or 40°, and mark the number of turns required to produce this effect. Take off the electricity, Theory of Electricity.

and having removed the connecting wire GC, turn the machine again ſlowly, till the index be in the ſame ſituation. The difference in the number of turns in this latter caſe, from the former, will ſhew pretty nearly the expenditure of fluid neceſſary to electrify only the plate of tin-foil. This difference will be found very trifling, when a low degree of electricity is employed; and to this it is neceſſary to confine the electrification, to prevent too great a diſſipation from the edges of the plate. Now replace the wire, and cauſe the index of the electrometer to point again at 30°; bring forward the plate DF, taking care to keep it juſt oppoſite and parallel to AB without touching it. No ſenſible change will be produced on the index, till the plate DF come within four or five inches of AB, and it may even be brought much nearer, without making the index ſink more than two or three degrees, unleſs a ſpark paſs between AB and DF. Remove DF again to the diſtance of two or three feet, and faſten to the ball N a piece of chain, or metallic thread, ſo that it may lie on the table. Now raiſe the electrometer again to 30°, and advance DF gradually towards AB. The index will gradually fall as DF advances, but will riſe again to its former height, if DF be carried back to its original ſituation.

Theſe appearances are eaſily explained in the principles laid down in N° 392, 393. For as DF advances towards AB, the redundant fluid in the latter repels a part of the fluid in DF towards the remote end of the wire EN, as is ſhewn by the ſeparation of the balls at N; hence an accumulation commences in AB, and the index of the electrometer HG falls juſt as if part of the fluid in the prime conductor were communicated to AB. When DF is made to communicate with the floor, much more electricity is repelled from DF, according as it approaches nearer to AB; but, by reaſon of the communication, the electrometer at N gives no ſigns of electricity.

If, inſtead of connecting AB with the prime conductor, we adapt to the wire GC, at the extremity G, a metallic plate of the ſame dimenſions as AB, with an electrometer attached to it next AB, and if this apparatus be any how electrified, and the ſeparation of the balls at H be noted, before DF, which communicates with the floor, be approached, on attending to the charges, it will be ſeen, that the divergency of the balls correſponds very nearly to the diſtance of DF, as is required by the theory.

Now, while the plates are near each other, eſpecially if DF communicates with the floor, if we ſuſpend a pith ball by a ſilk thread between AB and DF, the ball will be ſtrongly attracted by either of theſe plates that is neareſt to it, ſuppoſe DF; and, having touched this, it will be immediately repelled, and drawn towards AB, by which it will be again repelled to DF, and it will thus be driven backwards and forwards like the electrified ſpider deſcribed in N° 126, as long as any electricity remains in either of the plates. In the mean time, the index of the electrometer at H will gradually deſcend, till the motion of the pith ball ceaſes.

All theſe appearances are more remarkable, according as the plates are nearer to each other, and when they come in contact, the phenomena are the moſt complete.

If, when the plates are charged, we approach one end of a bended wire, (having a downy feather at each end, to the plate DF, and bring the other to AB, we ſhall obſerve the feathers ſpread out their fibres to the plates, and then the equilibrium will be reſtored, or the plates will be diſcharged.

Theory of Electricity.

Having, by means of this experiment, brought again into view the phenomena of charging and diſcharging a coated electric, we are prepared to explain the theory of the Leyden phial, which can eaſily be done by recurring to the important theorem of the diſpoſition and actions of four parallel plates, ſo fully detailed in N° 392.

416 Theory of the Leyden phial.

The following obſervations will alſo afford ſome idea of the manner in which the fluid is diſpoſed in the ſubſtance of the glaſs.

It fully appears from what has been ſaid in N° 409. that the electric fluid is not able to penetrate a plate of glaſs without breaking it; and yet it ſeems able to penetrate to a very ſmall depth, we might almoſt ſay, an imperceptible depth, within the ſurface of the glaſs.

Let ACGM, fig. 118. repreſent a flat plate of glaſs, or any other ſubſtance which will not ſuffer the electric fluid to paſs through it, ſeen edgeways; and let $BbdD$, and $EefF$, or Bd and Ef, as we ſhall call them for ſhortneſs, be two plates of conducting matter of the ſame ſize, placed in contact with the glaſs, oppoſite to each other; and let Bd be poſitively electrified; and let Ef communicate with the ground; and let the fluid be ſuppoſed either able to enter a little way into the glaſs, but not to paſs through it, or unable to enter it at all; and if it is able to enter a little way into it, let $bB\delta d$, or $b\delta$ as we ſhall call it, repreſent that part of the glaſs, into which the fluid can enter from the plate Bb, and $e\varphi$ that which the fluid from Ef can enter. By the above mentioned propoſition, N° 134. it appears that if be, the thickneſs of the glaſs, is very ſmall in reſpect of bd, the diameter of the plates, the quantity of redundant fluid forced into the ſpace Bd or $B\delta$, (that is, into the plate Bd, if the fluid is unable to penetrate at all into the glaſs, or into the plate Bd, and the ſpace $b\delta$, together if the fluid is able to penetrate into the glaſs) will be many times greater than what would be forced into it by the ſame degree of electrification, if it had been placed by itſelf; and the quantity of fluid driven out of $E\varphi$ will be nearly equal to the redundant fluid in $B\delta$.

If a communication be now made between $B\delta$ and $E\varphi$ by the canal NRS, the redundant fluid will run from $B\delta$ to $E\varphi$; and if in its way it paſſes through the body of any animal, it will, by the rapidity of its motion produce in it that ſenſation, called a *ſhock*.

It appears from N° 392, that, if a body of any ſize was electrified in the ſame degree as the plate Bd, and a communication was made between that body and the ground, by a canal of the ſame length, breadth, and thickneſs as NRS; that then the fluid in that canal would be impelled with the ſame force as that in NRS, ſuppoſing the fluid in both canals to be incompreſſible; and conſequently, as the quantity of fluid to be moved, and the reſiſtance to its motion, is the ſame in both canals, the fluid ſhould move with the ſame rapidity in both: and there ſeems no reaſon to think that the caſe will be different, if the communication is made by canals of real fluid.

Therefore, in the opinion of Mr Cavendiſh, as great a ſhock would be produced by making a communication between the conductor and the ground, as between the two ſides of the Leyden phial, by canals of the ſame length, and ſame kind. This ſeems a neceſſary conſequence of this theory; as the quantity of fluid which paſſes through the canal is, by the ſuppoſition, the ſame in both; and there is the greateſt reaſon to think, that the rapidity with which it paſſes, will be nearly, if not quite, the ſame in both.

It may be worth obſerving, that the longer the canal NRS is, by which the communication is made, the leſs will be the rapidity with which the fluid moves along it; for the longer the canal is, the greater is the reſiſtance to the motion of the fluid in it; whereas the force with which the whole quantity of fluid in it is impelled, is the ſame whatever be the length of the canal. Accordingly it is found in melting ſmall wires, by directing a ſhock through them, that the longer the wire, the greater charge it requires to melt it.

As the fluid in B δ, is attracted with great force by the redundant matter in E φ, it is plain that if the fluid is able to penetrate at all into the glaſs, great part of the redundant fluid will be lodged in *b d*, and in like manner there will be a great deficiency of fluid in *e* φ. But in order to form ſome eſtimate of the proportion of the redundant fluid, which will be lodged in *b* δ: let the communication between E *f* and the ground be taken away, as well as that by which B *d* is electrified; and let ſo much fluid be taken from B δ, as to make the redundant fluid therein equal to the deficient fluid in E φ. If we ſuppoſe that all the redundant fluid is collected in *b* δ, and all the deficient in E φ, ſo as to leave B *d* and E *f* ſaturated; then as the electric repulſion is inverſely as the ſquare of the diſtance, a particle of fluid placed anywhere in the plane *b d*, except near the extremities *b* and *d*, will be attracted with very near as much force by the redundant matter in *e* φ, as it is repelled by the redundant fluid in *b* δ. Hence it follows, that if the depth to which the fluid can penetrate is very ſmall in reſpect of the thickneſs of the glaſs, but yet is ſuch that the quantity of fluid naturally contained in *b* δ or *e* φ, is conſiderably more than the redundant fluid in B δ; then, as the repulſion is inverſely as the ſquare of the diſtance, almoſt all the redundant fluid will be collected in *b* δ, leaving the plane B *d* not very much overcharged; and in like manner E *f* will be not very much undercharged: if the repulſion were inverſely as ſome higher power than the ſquare, B *d* will be very much overcharged, and E *f* very much undercharged: and if the repulſion were inverſely as ſome lower power than the ſquare, B *d* will be very much undercharged, and E *f* very much overcharged.

417 It is a part of Dr Franklin's theory, that no electric fluid can be thrown into one ſide of a coated plate, unleſs an equal quantity be at the ſame time abſtracted from the other ſide; and that conſequently the charged plate contains no more fluid than before it was charged. We find, indeed, that one ſide of the plate will not receive a charge, unleſs the other ſide at the ſame time communicate with the ground. He infers the ſame conſequence from the circumſtance, that if a jar be diſcharged through a perſon when inſulated, the perſon is not found electrified; the neceſſary conſequence of which is, according to Dr Franklin, that any number of jars may be charged by the ſame turns of a machine, provided that the outſide of one jar communicates with the inſide of the next ſucceſſively, while the outſide of the laſt has a communication with the ground. He found, however, by experiment, that a greater number of turns was neceſſary, than his theory required; but he attributed this circumſtance to the diſſipation of the fluid into the air. But we learn from our theory that the redundant matter in the plate that communicates with the ground is leſs than the redundant fluid in the other plate in the proportion of $n-1$ to n: and that the proportion of redundant fluid in the next plate or jar is no greater. If we have any number of jars, the charge of the *m*th jar in the ſeries, will be $\overline{\frac{n-1}{m}}\Big|^{m}$. If the charge of the firſt jar or $n=60$, that of the 10th will $=51$ nearly.

Though a coated plate will not receive a charge, unleſs one ſide communicate with the ground, it may however be rendered electrical, as appears when we attempt to charge it while inſulated. For when we attempt to electrify one ſide, the other gives a ſpark which proves this to be electrified alſo. Again, when a charged phial is diſcharged by means of an inſulated diſcharger, it always remains electrical, poſitively or negatively, according as the body from which it was charged was poſitive or negative.

418 Miſtake of Wilcke.

It was ſuppoſed by Wilcke, that when a jar is charged by connecting one ſide of it with the prime conductor, and the other with the rubber, it is neutral on both ſides. But if this were the caſe, it could not be diſcharged; and in fact, it will be found by experiment to be equally active on both ſides.

419 Method of verifying the theory.

It is ſcarceſy neceſſary to remark, that the theory of the Leyden phial, and that of a coated plate, are the ſame; and hence we have an eaſy method of comparing the theory with experiment, by taking two plates of the ſame kind of glaſs, and of an equal thickneſs, but different in the extent of coated ſurface. If we charge both plates, by means of very long conducting wires attached to both ſides, we are to meaſure how often the charge of the leſſer plate is contained in the greater, which is eaſily done by the following method of Mr Cavendiſh.

420 Cavendiſh's method of meaſuring a charge.

When a jar is charged, obſerve the electrometer that is connected with it, and immediately communicate the charge to another equal jar, the perfect equality of which has been previouſly aſcertained by the methods, which will preſently appear. Again, note the electrometer. This will give the elevation, that indicates one half, independent of all theory. Now electrify a jar, or a ſeries of equal jars, to the ſame degree as the firſt, and communicate the charge to a coated plate of mirror glaſs, diſcharging the plate after each communication, till the electrometer reaches the degree that 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

When *x* is ſmall in proportion to 1, we ſhall come very near the truth, by multiplying the number of communications by 1,444, ſubtracting 0,5 from the product. The remainder ſhews how often the charge of the plate is contained in that of the jars or $\frac{1}{x}$.

421 The important diſcovery of Franklin, that the charge of coated glaſs reſides in the glaſs, and not in the coating, led Beccaria to a no leſs important diſcovery; namely, that in a charged plate of glaſs, and probably of any other electric, there are ſeveral ſtrata, inconceivably thin, that are alternately in a poſitive and negative ſtate, and that the number of theſe ſtrata increaſes as the electrification is continued.

This diſpoſition of the ſurfaces of electric plates explains many phenomena; particularly the experiments with charged plates deſcribed in N° 151. and ſome curious appearances obſerved by Beccaria, and ranked by him under the head of *vindicating electricity*.

They are thus deſcribed by Mr Cavallo.

422 Beccaria's vindicating electricity. 1. AB, *a b*, fig. 119, repreſents a plate of glaſs, coated on both ſides with the two metallic coatings, CD, *c a*, which are not ſtuck to the plate, but only laid upon it.

From the upper coating CD, three ſilk threads proceed, which are united at their top H, by which the ſaid coating may be removed from the plate in an inſulated manner, and may be preſented to an electrified electrometer as repreſented in fig. 120. in order to examine its electricity. FG is a glaſs ſtand, which inſulates and ſupports the plate, &c.

2. Let the plate AB, *a b*, be charged in the common manner, by means of an electrical machine, ſo that its ſurface AB may acquire one kind of electricity, (which may be called K) and the oppoſite ſurface *a b* may acquire the contrary electricity, (which we ſhall call L). Then, if the coating CD be removed from the plate, and be preſented to an electrified electrometer, as repreſented in fig. 120, it will be found poſſeſſed of the electricity K, viz. of the ſame kind with that which was communicated to the ſurface AB of the glaſs plate; from whence it is deduced, that the ſurface AB has imparted ſome of its electricity to the coating. Now, this diſpoſition of the charged plate to give part of its electricity to the coating, is what the learned F. Beccaria nominates the *negative vindicating electricity*.

3. If the coating be again and again alternately laid upon the plate and removed, its electricity K will be found to decreaſe gradually, till after a number of times (which is greater or leſs, according as the edges of the plate inſulate more or leſs exactly), the coating will not appear at all electrified. This ſtate is called the *limit* of the two contrary electricities; for if now the above-mentioned operation of coating and uncoating the plate be continued, the coating will be found poſſeſſed of the contrary electricity, viz. the electricity L. This electricity, L, of the coating is weak on its firſt appearance; but it gradually grows ſtronger and ſtronger till a certain degree; then inſenſibly decreaſes, and continues decreaſing until the glaſs plate has entirely loſt every ſign of electricity.

By this change of electricity in the coating, it is deduced, that the ſurface AB of the glaſs plate changes property; and whereas at firſt it was diſpoſed to part with its electricity, now, (viz. beyond the limit of the two contrary electricities) it ſeems to vindicate its own property, that is, to take from the coating ſome electricity of the ſame kind with that of which it was charged: hence this diſpoſition was by F. Beccaria called the *poſitive vindicating electricity*.

4. This poſitive vindicating electricity never changes, though the coating be touched every time it is removed. It appears ſtronger, and laſts a very conſiderable time after the plate has been diſcharged; which is a very ſurpriſing property of glaſs, and probably of all good and ſolid electrics.

5. If, ſoon after the diſcharge of the plate, the coating be alternately taken from the plate, and replaced, but with the following law, viz. that when the coating is upon the plate, both coatings be touched at the ſame time, and when the coating is cut off, this be either touched or not: then the ſurface AB of the plate, on being uncoated every time, takes a quantity of electricity, which it alternately loſes every time it is coated.

6. On removing the coating in a dark room, a flaſh of light appears between it and the glaſs, which is ſtill more conſpicuous if the coating be removed by the fingers being applied immediately to it, viz. not in an inſulated manner, becauſe, when the coating is not inſulated, the glaſs plate can give to, or receive from it, more of the electric fluid, and that more freely, than otherwiſe.

7. It is obſervable, that in the negative vindicating electricity, the glaſs loſes a greater or leſs portion of electricity in an inverſe proportion of the charge given to the plate, viz. the part loſt is greater when the charge has been the weaker; for in the poſitive vindicating electricity, the force of receiving electricity is the ſtronger, when the charge has been ſtronger, and contrarywiſe.

8. If, after every time that the coating CD is removed, the atmoſpheres E, *e*, that is, the air contiguous to the ſurface of the glaſs plate, be examined, they will be found electrified as in the following table, viz. the threads of an electrometer, brought within one or two inches, or more, of the ſurfaces AB, *a b*, will diverge with electricities contrary to thoſe expreſſed in the table.

During the time of the negative vindicating Electricity	the air E. if the plate has been charged	moderately	moderately L
		high - -	o
		very high -	moderately K
	the air *e* is electrified L.		

During the time of the poſitive vindicating Electricity	the air E	are electrified L.
	The air *e*	

423 Theory of the electrophorus. The theory of coated glaſs naturally leads us to that of the electrophorus; for though this apparatus is not exactly ſimilar to a charged plate, as has been ſuppoſed by ſome; there is yet a conſiderable reſemblance in the phenomena.

We have given a deſcription of the electrophorus, and of its effects in Chap. X. of Part III. where we alſo ſtated, that, for illuſtrating the theory, it was proper to to make the ſeveral parts of the apparatus of conſiderable thickneſs, as the more inſtructive but minute changes are thus greatly increaſed, though the ſhowy and brilliant phenomena are not ſo remarkable. Fig. 121. repreſents a ſection of the three parts of the apparatus in contact, where ABCD is the electric *cake*, CDEF the *ſole*, and ABHG the *cover*. They are here repreſented lying horizontally on each other; but for experiment, it will be moſt convenient to have them fixed vertically to glaſs ſupporters, furniſhed with leaden feet to keep them ſteady.

We might here give a mathematical explanation of the phenomena of the electrophorus; and the actions of every part of the apparatus might eaſily be ſtated by means of the propoſitions in N° 308 to 314, and the correſponding ones in N° 228—335, taking into conſideration the true law of action. But as this would be going over again much of the ground that we have already trodden, where our readers might not be pleaſed with being obliged to follow us; we ſhall treat the ſubject in a manner ſomewhat more popular, the reſult, however, of ſtrict mathematical reaſoning.

424 Diſpoſition of fluid in the electrophorus.

Having related the general phenomena in N° 207, we have now to conſider only the diſpoſition of fluid in the various parts of the apparatus in various ſituations, and the mutual forces that operate between them.

425 1. Its primitive ſtate.

We ſhall conſider the inſtrument under various ſtates.

1. When the cake is left to cool after being made, it becomes negative by cooling; and if it were by itſelf, the ſurface on both ſides would be negative to a conſiderable thickneſs near the edges; and the fluid would probably grow denſer by degrees towards the middle, where it would have its natural denſity. This diſpoſition may be inferred from N° 371, 372. But as it cools in conjunction with the ſole, the attraction of the redundant matter in the cake for the moveable fluid in the ſole, muſt diſturb its uniform diffuſion in the ſole, and cauſe it to approach the cake. And as this probably happens while the cake is ſtill in a conducting ſtate, the diſpoſition of its fluid will be different from what is deſcribed above, and the final diſpoſition of the fluid in the cake and ſole will reſemble that given in N° 371. where the plates may repreſent the cake and ſole. It will be ſufficient at preſent to conſider the cake and ſole as divided into only two ſtrata; one containing redundant fluid, and the other deficient, neglecting the neutral ſtratum interpoſed between them in each. The cake then conſiſts of a ſtratum AB *b a* A, containing redundant matter, and a ſtratum *a b* CD containing redundant fluid; and the ſole of a ſtratum DC *n m* containing redundant fluid; that is, all that belongs naturally to the ſpace DC FE, and of a ſtratum *m n* FE, containing redundant matter. We may call this the *primitive ſtate* of the cake and ſole; and if this is once changed by communication with unelectrified bodies, it can never be recovered without new excitation.

426 2. Common ſtate.

2. If the ſole is touched by a body that communicates with the ground, fluid will enter it, till the repulſion of the redundant *fluid* in the ſole for a ſuperficial particle is equal to the attraction of the redundant *matter* in the cake for the ſame particle. What we have ſaid concerning infinitely extended plates rendered neutral on one ſide, may ſuffice to give a notion of the preſent diſpoſition of the fluid in the ſole. The inferior ſurface will be neutral; and the denſity of the fluid will increaſe towards 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 may be called the *common ſtate* of the electrophorus.

427 3. Place the cover GHBA on the cake. A particle Z, at the upper ſurface of the cover, muſt be more attracted by the redundant matter in the ſtratum AB *b a* than it will be repelled by the redundant fluid in the remoter ſtrata; for the fluid in the cake is leſs than when it is in its natural ſtate, and therefore Z is attracted by the cake. The redundant fluid which has entered the remote ſide of the ſole is leſs than what would be ſufficient to 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. Therefore the particle Z, lying immediately within the ſurface GH, is on the whole attracted; ſome fluid will move toward the cake, and its natural ſtate of uniform diffuſion in the cover will be changed into a violent ſtate, in which the fluid will be compreſſed on the ſurface AB, and abſtracted from the ſurface GH. There will now be a ſtratum G *g p* H, containing redundant matter, and another *g p* BA containing redundant fluid. But this diſpoſition will diſturb the arrangement that had taken place in the ſole, and had rendered it neutral on the inferior ſurface. The particle Z ſituated in that ſurface, will be more repelled by the compreſſed fluid in the ſtratum *g p* CA than it will be attracted by the equivalent more remote redundant matter in GH *p g*. Fluid is now therefore diſpoſed to quit the ſurface EF, and the ſole will appear poſitively electric, but in a ſmall degree only, if the cover be thin. All this may be obſerved by attaching a ſmall ball electrometer to the lower ſurface of the ſole, or touching the ſole, with it, and then trying its electricity by excited glaſs, or ſealing-wax.

428 4. A particle of fluid Z, placed immediately without the ſurface GH, is more attracted by the deficient ſtratum GH *g q* and by AB *b a*, than it is repelled by the redundant ſtrata beyond them, and hence the cover muſt be ſenſibly negative. This is the common ſtate of the whole apparatus after ſetting on the cover. The lower ſurface of the ſole is ſlightly poſitive, and the upper ſurface of the cover more ſenſibly negative. A ſmart ſpark will be ſeen between the apparatus and the finger,' and fluid will enter, till the attraction of the redundant matter in AB *b a* balances the repulſion of the redundant fluid in DC FE.

429 Its neutral ſtate.

5. A ſpark may now be obtained from the ſole; for it was faintly poſitive before, and there is now the additional action of the fluid that has entered into the cover. Part of the fluid in the ſole is therefore diſpoſed to fly to any body that is preſented to it. But when this transference has taken place, the equilibrium at the ſurface GH is deſtroyed, and this ſurface again becomes negative, and will attract fluid, although the cover contains already 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 may be reſtored at GH; but it will be deſtroyed again at EF, from which a poſitive ſpark may be obtained, leaving GH negative in its turn. This would go on for ever, in a ſeries of communications continually diminiſhing ſo as at laſt to become inſenſible, if the three parts of the electrophorus be thin. This ſhews the neceſſity of making them otherwiſe, if the inſtrument be intended for illuſtrating the theory.

430 Its charged ſtate.

The equilibrium is at length completed at the ſurfaces GH and EF, both of which are neutral with reſpect to ſurrounding bodies, although both the cover and ſole contain more than their natural ſhare of electric fluid. This ſtate of the apparatus may be called its *neutral ſtate;* and it 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 ſhall have a bright, pungent ſpark, and a ſmall ſhock. If this be the object of the experiment, the ſtate N° 428. which gives occaſion to it may be called the *charged ſtate* of the electrophorus.

When the apparatus has been thus rendered neutral with reſpect to ſurrounding bodies, it may continue in this ſtate for any length of time, without its capability of producing the other phenomena being diminiſhed, provided that no fluid paſs from the cover to the cake.

431 Its charging ſtate.

6. Now if the cover be removed to a diſtance, both parts of the apparatus will exhibit ſtrong marks of electricity. For the cover contains much redundant fluid, and muſt therefore appear ſtrongly poſitive; it will give a briſk ſpark, which may be employed for any purpoſe, particularly for charging a jar poſitively by the knob, if we juſt touch the cover with the knob. Again, the ſole will attract fluid, or it will be negative, though it contains more than its natural quantity of fluid; it will therefore take a ſpark. The ſole, therefore, in the abſence of the cover, may be employed to charge a jar negatively by the knob. By being touched with the finger, or with the knob of a jar held in the hand, it will be reduced to the common ſtate deſcribed in N° 426.; and now all the former experiments may be repeated. We may call this the *active* or the *charging ſtate* of the electrophorus.

432

7. If the electrophorus be not inſulated, a ſhock may, however, be obtained, by touching firſt the ſole, and then the cover, without taking off the finger; but will not be ſo ſmart as when the negative cover is touched at the ſame time with the ſole. The difference will, however, be ſcarcely perceptible when the pieces are thin.

433

8. If the apparatus has not been inſulated, the cover when put on will afford a ſpark, in the manner already mentioned, and this will be rather ſtronger than when it is inſulated; for the fluid being allowed to eſcape from the ſole, does not obſtruct the entry of fluid into the cover. If then, without removing the finger from the cover, we touch the ſole, we feel nothing; but if we firſt touch the ſole, and then, without removing the finger from it, touch the cover, we ſhall obtain a ſhock. By this ſeries of alternate touches, the period of the electrophorus is completed. For it is firſt charged or rendered neutral, by touching the plates in contact; then, by touching both when ſeparate, the whole is reduced to the common ſtate. When after having been in the *neutral ſtate* they are ſeparated, they have oppoſite electricities, the *ſole* having that of the cake. When brought together, each in the *common ſtate*, they have oppoſite electricities, the *cover* having that of the cake.

434 Method of renewing its activity.

9. By being long expoſed to the air without the cover, the electrophorus gradually loſes its activity. This may however be again reſtored in ſeveral ways. One of the moſt obvious methods is, to produce a freſh excitation of the reſinous cake; and this is beſt done by rubbing it with a piece of new flannel, of cat or hare's ſkin, or, what anſwers ſtill better, a piece of mole ſkin; This friction renders the cake negative. It may alſo be electrified negatively, by placing on it a jar charged negatively in the inſide, and then touching the knob of the jar with any conducting body that communicates with the ground. By this means it may be very ſtrongly excited, if the jar be large, and if the cake be covered with a piece of tinfoil, that comes cloſely in contact with its whole ſurface. But one of the moſt expeditious and effectual methods of reſtoring the energy of the cake, will be to electrify it by means of an electrical machine, while the ſurface of the cake is connected with the rubber.

The only important part of the theory of electricity which we have yet to conſider, is that of the condenſer, but as this will be greatly elucidated by an application of Coulomb's experiments on *inſulators*, we ſhall delay it till we give an account of theſe in the article ELECTROMETER.

PART V.

ON ATMOSPHERICAL ELECTRICITY.

THE phenomena of electricity, that we have hitherto deſcribed, are ſufficiently curious, and many of them extremely intereſting; but they are trifling, when compared with thoſe that are now to come under our conſideration. In the preſent part of our article, we are to view the electric fluid as one of the principal agents, employed to produce ſome of the moſt remarkable and aſtoniſhing phenomena of nature. We are about to prove, by a ſeries of the moſt ſatisfactory experiments, that thunder and lightning are merely the effects of a vaſt exploſion of accumulated electricity in the atmoſphere.

Chap. I. *Of Thunder.*

Sect. I. *Of the Identity of Electricity and Lightning.*

435 Identity of electricity and lightning.

It is not ſurpriſing that the experiments in which the electric ſpark is made to produce the effects which we have recounted in the third part of this article, ſhould have led philoſophers to conceive a ſimilarity between theſe effects, and thoſe produced by lightning.

436 Conjectured by Wall and Grey.

Dr Wall and Mr Grey ſeem to have fancied a reſemblance between thunder and the ſnapping noiſe produced by applying the fingers to an excited electric: but how ſuch a reſemblance ſhould ſtrike them, is not eaſy to conceive; and indeed it ſeems to have been merely a bold conjecture.

437 By the abbe Nollet.

The abbé Nollet appears to have formed the firſt rational idea of their ſimilitude, and expreſſes himſelf on the ſubject in the following remarkable manner.

"If any one ſhould take upon him to prove from a well connected compariſon of phenomena, that thunder is in the hands of nature what electricity is in ours; that the wonders which we now exhibit at our pleaſure, are little imitations of thoſe great effects that frighten us, and that the whole depends upon the ſame mechaniſm: if it can be demonſtrated that a cloud prepared by the action of the winds, by heat, by a mixture of exhalations, &c. is oppoſite to a terreſtrial object; that this is the electrified body, and at a certain proximity to that which is not: I avow that this idea, if it was well ſupported, would give me a great deal of pleaſure; and in ſupport of it, how many ſpecious reaſons preſent themſelves to a man who is well acquainted with electricity! The univerſality of the electric matter, the readineſs of its action, its inflammability, and its activity in giving fire to other bodies, its property of ſtriking externally and internally even to their ſmalleſt parts, the remarkable example we have of this effect in the Leyden experiment, the idea which we might truly adopt in ſuppoſing a greater degree of electric power, &c. all theſe points of analogy which I have been ſome time meditating, begin to make me believe, that by taking electricity for the model, one might form to one's ſelf, in reſpect to thunder and lightning, more perfect and more probable ideas than have hitherto been offered."

438 Suppoſed by Dr Franklin.

But the firſt electrician who formed a plan for aſcertaining the truth of this hypotheſis, was Dr Franklin, who truly realized the fable of Prometheus in bringing down fire from heaven.

Before we relate Dr Franklin's experiments, we ſhall ſtate the points of reſemblance which led him to think of making them.

He begins his account of the ſimilarity of the electric fluid and lightning, by cautioning his readers not to be ſtaggered at the great difference of effects in point of degree; ſince that was no argument of any diſparity in their nature. It is no wonder, ſays he, if the effects of the one ſhould be ſo much greater than thoſe of the other. For if two gun-barrels electrified will ſtrike at two inches diſtance, and make a loud report; at how great a diſtance will 10,000 acres of electrified cloud ſtrike and give its fire, and how loud muſt be the crack!

439 Similar effects of lightning and electricity.

1. Flaſhes of lightning, are generally ſeen crooked and waving in the air. The ſame is the electric ſpark always, when it is drawn from an irregular body at ſome diſtance. He might have added, when it is drawn by an irregular body, and through a ſpace in which the beſt conductors are diſpoſed in an irregular manner, which is always the caſe in the heterogeneous atmoſphere of our globe.

2. Lightning ſtrikes the higheſt and moſt pointed objects in its way, preferably to others; as high hills and trees, towers, ſpires, maſts of ſhips, points of ſpears, &c. In like manner, all pointed conductors receive or throw off the electric fluid more readily than thoſe which are terminated by flat ſurfaces.

3. Lightning is obſerved to take the readieſt and beſt conductor; ſo does electricity in the diſcharge of the Leyden phial.

4. Lightning ſets fire to inflammable bodies; ſo does electricity.

5. Lightning, as well as electricity, fuſes metals.

6. Lightning rends ſome bodies. The ſame does electricity.

7. Lightning has often been known to ſtrike people blind. And a pigeon, after a violent ſhock of electricity, by which the Doctor intended to have killed it, was obſerved to have been ſtruck blind likewiſe.

8. Lightning deſtroys animal life. Animals have likewiſe been killed by the ſhock of electricity.

9. Magnets have been obſerved to loſe their virtue, or to have their poles reverſed by lightning. The ſame effect has been produced by electricity.

440 Franklin's propoſal for verifying theſe conjectures.

Reaſoning on the ſimilarity of theſe effects, he formed the bold attempt to draw down lightning from the clouds, and examine by experiment whether he could produce effects ſimilar to thoſe of nature. Having obſerved the effects of pointed conductors in attracting the electric fluid more eaſily than thoſe of any other form, he conceived that pointed rods of iron, fixed in the air, when the atmoſphere was loaded with lightning, might draw from it the matter of thunderbolts, without noiſe or danger, into the body of the earth. His account of this ſuppoſition is given by himſelf in the following words: "The electric fluid is attracted by points. We do not know whether this property be in lightning; but ſince they agree in all the particulars in which we can already compare them, it is not improbable that they agree likewiſe in this. Let the experiment be made."

441 His experiments to bring down lightning from the clouds.

In the year 1752, while waiting for the erection of a ſpire in the city of Philadelphia, not imagining that a pointed rod of a moderate height could anſwer the purpoſe; at laſt it occurred to him, that, by means of a common kite, he could have readier acceſs to the higher regions of the atmoſphere than any other way whatever. Preparing, therefore, a large ſilk handkerchief, and two croſs ſticks of a proper length on which to extend it, he took the opportunity of the firſt approaching thunder-ſtorm to take a walk into a field where there was a ſhed proper for his purpoſe. But dreading the ridicule which too often attends unſucceſsful attempts in ſcience, he communicated his intention to nobody but his ſon, who aſſiſted him in raiſing the kite. A conſiderable time elapſed before there was any appearance of ſucceſs. One very promiſing cloud had paſſed over the kite without any effect; when, juſt as he was beginning to deſpair, he obſerved ſome looſe threads of the hempen ſtring to ſtand erect, and avoid one another, juſt as if they had been ſuſpended by the conductor of a common electrical machine. On this he preſented his knuckle to a key which was faſtened to the ſtring, and thus obtained a very evident electric ſpark. Others ſucceeded, even before the ſtring was wet; but when the rain had begun to deſcend, he collected electric fire pretty copiouſly. We are told, that when he ſaw the fibres of the ſtring erect themſelves, he uttered a deep ſigh, and wiſhed that moment to be his laſt, feeling that by this diſcovery his name would be immortalized. He had afterwards an inſulated iron rod to draw the lightning into his houſe; and performed almoſt every experiment with real lightning, that had before been done with the artificial repreſentations of it by electrical machines. That he might loſe no opportunity of making his experiments, he connected two bells with his inſulated rod; and theſe by their ringing, gave him notice whenever his apparatus was electrified by the lightning.

Although we have recounted Dr Franklin's experiments firſt, he was not however, the firſt who verified his own hypotheſis. This was done in France, about a month before Dr Franklin's experiments with the kite.

442
The identity of lightning and electricity firſt diſcovered in France.

The moſt active perſons were two French gentlemen, Meſſrs Dalibard, and Delor. The former prepared his apparatus at Marly la ville, ſituated about five or ſix leagues from Paris; the latter at his own houſe, which was on ſome of the higheſt ground in that capital. Mr Dalibard's apparatus conſiſted of an iron rod, 40 feet long, the lower extremity of which was brought into a ſentry box where the rain could not enter; while on the outſide, it was faſtened to three wooden poſts, by ſilken ſtrings defended from the rain. This machine was the firſt that happened to be favoured with a viſit from the ethereal fire. Mr Dalibard himſelf was not at home; but, in his abſence he had intruſted the care of his apparatus to one Coiſier a joiner, who had ſerved 14 years among the dragoons, and on whoſe courage and underſtanding he could depend. This artiſan had all the neceſſary inſtructions given him; and was deſired to call ſome of his neighbours, particularly the curate of the pariſh, whenever there ſhould be any appearance of a thunder-ſtorm. At length the long-expected event arrived. On Wedneſday the 10th of May 1752, between two and three in the afternoon, Coiſier heard a pretty loud clap of thunder. Immediately he ran to the machine, taking with him a vial furniſhed with a braſs wire; and preſenting the wire to the end of the rod, a ſmall ſpark iſſued from it with a ſnap like that of a ſpark from an electrified conductor. Stronger ſparks were afterwards drawn, in the preſence of the curate and a number of other people. The curate's account of them was, that they were of a blue colour, an inch and a half in length, and ſmelled ſtrongly of ſulphur. In taking them, he received a ſtroke on his arm, a little below the elbow; but he could not tell whether it came from the braſs wire inſerted into the phial, or from the bar. He did not attend to it at the time, but the pain continuing, he uncovered his arm when he went home, in the preſence of Coiſier. A mark was perceived round it, ſuch as might have been made with a blow of the wire on his naked ſkin.

Eight days after, Mr Delor witneſſed the ſame appearances at his own houſe, though only a cloud paſſed over, without either thunder or lightning. His apparatus differed little from that of Mr Dalibard, except that his rod was 99 feet high, and anſwered rather better than that of the other gentleman. As it was found that only a ſmall quantity of electric fluid could be collected by a ſingle pointed rod, theſe experimentaliſts added to this apparatus a number of inſulated iron bars, communicating with the pointed iron conductor, conſtituting what they called a magazine of electricity.

443 Dr Franklin having proved the identity of lightning and electricity, was deſirous of aſcertaining whether the electricity produced from the clouds was poſitive or negative. The firſt time he ſucceeded in making an experiment for this purpoſe, was on the 12th of April 1753, when the lightning appeared to be negative. Having found that the clouds electrified negatively for eight ſucceſſive thunder-guſts, he concluded that their electricity was always negative, and ſet about forming a theory to account for this. But he afterwards found he had concluded too ſoon. For on the ſixth of June following, he met with one cloud which was electrified poſitively; upon which he corrected his former theory, but did not ſeem able perfectly to ſatisfy himſelf with any other. The Doctor ſometimes found the clouds would change from poſitive to negative electricity ſeveral times in the courſe of one thunder-guſt, and he once obſerved the air to be ſtrongly electrified during a fall of ſnow, when there was no thunder at all.

The experiments of Dr Franklin and M. Dalibard, were ſoon known over all Europe, and the electricians of every country were eager to participate in the glory and ſatisfaction to be derived from ſuch grand undertakings. M. M. Mazeas, Monnier, and de Romas in France, Canton and Wilſon in England, and above all, Beccaria in Italy, made a number of intereſting experiments on the electricity to be drawn from the clouds, and ſoon diſcovered that ſigns of electricity might be obtained, not only during thunder-ſtorms, but almoſt at all times, and in every kind of weather. But before we relate theſe obſervations, we muſt conclude our preſent ſubject. We ſhall only here deſcribe Dr Prieſtley's method of conſtructing a thunder-rod for making ſuch obſervations.

444
Method of conſtructing thunder rods.

"On the top of any building, which will be the more convenient if it ſtand upon an eminence, erect a pole as tall as a man can well manage, having on the top of it a ſolid piece of glaſs or baked wood a foot in length. Let this be covered with a tin or copper veſſel in the form of a funnel, to prevent its ever being wetted. Above this, let there riſe a long ſlender rod, terminating in a pointed wire, and having a ſmall wire twiſted round its whole length, to conduct the electricity the better to the funnel. From the funnel make a wire deſcend along the building, about a foot diſtance from it, and be conducted through an open ſaſh, into any room which ſhall be moſt convenient for making the experiments. In this room let a proper conductor be inſulated, and connected with the wire coming in at the window. This wire and conductor, being completely inſulated, will be electrified whenever there is a conſiderable quantity of electricity in the air; and notice will be given when it is properly charged, either by Mr Canton's balls hung to it, or by a ſet of bells *".

SECT. II. *Of the Phenomena and Effects of Lightning.*

445 Progreſs of a thunder ſtorm.

A thunder-ſtorm commonly commences in the following manner. At firſt a low denſe cloud begins to form in a part of the atmoſphere which was previouſly clear; this cloud increaſes faſt, but only from its upper part, and ſpreads into an arched form, appearing like a large heap of cotton wool. Its lower ſurface is generally level, as if it reſted on a ſmooth plane. The wind is all this time very gentle, and frequently it is imperceptible.

Numberleſs ſmall ragged clouds, like teazled flakes of cotton, ſoon begin to make their appearance, moving about in various directions, and perpetually changing their irregular ſurface, appearing to increaſe by gradual accumulation. As they move about, they approach each other, and appear to ſtretch out their ragged arms towards each other; they do not often come in contact, but after approaching very near each other, they evidently recede, either in whole, or by bending away their ragged arms.

While this irregular motion continues, the whole maſs of ſmall clouds gradually approaches towards the large cloud which firſt appeared, and with which they finally coaleſce; frequently, however, uniting with each other into larger maſſes, before the general coaleſcence takes place. The upper cloud often increaſes by acceſſion of freſh vapour, without any aſſiſtance from the ſmaller maſſes. When this happens, its lower ſurface, which was before level and regular, becomes ragged, and ſtretches out its irregular tatters towards each other, and towards the earth. The clouds now thicken faſt, moving about ſwiftly in all directions, and flaſhes of lightning are ſeen to dart from one cloud to another; the wind now riſes or increaſes, generally blowing in ſqualls. The lightning becomes more frequent, ſtriking between the clouds and the earth, often in two places at once; flaſhes of various ſhapes and various brilliancy are produced, and frequently a vaſt expanſe of horizon appears in one blaze of light. The thunder is now heard to roar at a diſtance, gradually approaching nearer, and ſoon ſucceeded by heavy rain *.

The circumſtances to be noticed as attending a thunder-ſtorm, chiefly reſpect the form and colours of the lightning, the ſound of the thunder, and the devaſtations produced when an exploſion takes place between a cloud and ſome imperfectly conducting body on the ſurface of the earth.

446 Form of the flaſh.

The form of the flaſh is various, but in ordinary lightning it is generally angular, or *zig-zag*; this zig-zag is ſometimes larger than at others, and in ſome inſtances the flaſh is divided into ſeveral diſtinct currents. Theſe diverſities might be expected from the heterogeneous nature, and various conducting power, of the ſeveral ſubſtances which float in our atmoſphere. As theſe ſubſtances are placed in no certain order, the electric ſpark, in paſſing through the air, and ſtriking ſucceſſively from one of theſe bodies to another, as ſo many ſtepping ſtones irregularly placed, can ſeldom obſerve the ſame tract, and hence its zig-zag appearance.

Sometimes the flaſh appears as one denſe ball of fire, eſpecially when it ſtrikes from a cloud to any part of a building, when it is generally deſcribed as a globe of fire falling on the building.

447 Colours of the flaſh.

The colours of the flaſh are alſo various; pale ſtraw colour, vivid yellow, and various ſhades of blue, are the moſt prevailing tints. Theſe various colours probably depend on the different denſity of the air through which the light has paſſed, or perhaps, on its different nature. We found, when relating the experiments of Mr Morgan on the appearance of the electric light in rarefied air, that its colour varied with the degree of rarity produced in the exhauſted receiver; and from the experiments on paſſing the electric ſpark through various gaſes, we found that the colour of the light varied conſiderably with the nature of the gas through which it paſſed.

448 Clap of thunder always preceded by a flaſh of lightning.

Lightning very often appears without being ſucceeded by thunder, but we believe there is ſcarcely an inſtance where the latter is not preceded by the former; we ſay, *ſcarcely an inſtance*, for we have on record in the 77th volume of the Philoſophical Tranſactions, an account of a thunder-ſtorm that happened on the banks of the Tweed in 1785, in which an exploſion took place that killed a man and two horſes, but was not preceded by any flaſh. The reſpectable recorder of this account, Mr Brydone, was not himſelf a witneſs of the accident, but could not learn from the perſons whom he interrogated, (two Scotch peaſants), who had ſeen the accident, that there was any preceding flaſh of lightning. In ſuch ſingular circumſtances, and with ſuch doubtful authority, we ſhould be diſpoſed to ſuſpend our belief, and, until ſome ſimilar inſtance better authenticated ſhall occur, to take it for granted, that a clap of thunder is always preceded by a flaſh of lightning.

449 Sound of the exploſion.

The ſound which attends the exploſion of the lightning, varies according to the diſtance from which it is heard, and the nature of the country where the ſtorm takes place. At a little diſtance, it is generally a hoarſe grumbling noiſe, which appears to extend through a conſiderable part of the atmoſphere, and gradually dies away. If it be heard very near, the craſh is inſtantaneous, and exactly ſimilar to the exploſion of a cannon, when we are very near it at the time of its being fired.

When the exploſion begins very near, the ſnap begins with great ſmartneſs, and for ſome time reſembles the violent tearing of a piece of ſtrong ſilk; but it becomes more mellow as it proceeds to a greater diſtance.

If the country where the ſtorm happens be high and irregular, where there are numerous objects capable of reverberating the ſound, the exploſion conſiſts of a long and broken ſucceſſion of claps, the loudneſs of which varies more according to the nature and circumſtances of the reverberating objects, than according to the length of time which intervenes between the claps. In a level and low country, where there is no diverſity of reverberating objects, and particularly at ſea, the ſeries of exploſions is regular, and their loudneſs decreaſes as the length of time increaſes.

The exploſion of thunder differs from the ſnap produced by the electric ſpark, or even the exploſion of a jar or a battery, not only in its degree of loudneſs, but in

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* Prieſtley's *Hiſt.* part v. ſect. 1.

* *Beccaria Lett. del elettriciſmo.*

in its nature; it is a long-continued, rumbling, unequable noiſe. The long-continued roar of thunder, is certainly owing to the commencement and termination of the exploſion reaching our ears at different periods of time; and the unequally loud rumbling noiſe is owing to the different parts of the exploſion ſtriking the ear in a different manner.

450 Method of meaſuring the diſtance of the exploſion.

It will not be improper here to mention the method by which the diſtance of a thunder-ſtroke may be aſcertained. By obſerving the flaſh, and counting, by means of a watch with a *ſecond hand*, the number of ſeconds which elapſe between the appearance of the flaſh and the commencement of the roar, this may be eaſily effected; for we know that ſound travels at the rate of 186,768 feet in a minute: by reducing the time obſerved between the flaſh and the report, into ſeconds, and allowing for each its proper number of feet, we obtain, with ſufficient accuracy, the diſtance of the ſtroke from the place of obſervation.

451 Manner in which the exploſion takes place.

To underſtand the manner in which the exploſion of thunder is produced, we muſt obſerve, that the air of the atmoſphere is often arranged in ſtrata, and theſe ſtrata are bounded by clouds. That the clouds are ſtratified, is very evident. From various cauſes, to be explained hereafter, theſe ſtrata, or the oppoſite ſurfaces of a particular ſtratum, are poſſeſſed of oppoſite ſtates of electricity, or the ſtratum becomes charged as the plate of air between the two coated boards, deſcribed in N° 235. Numberleſs experiments have proved, that during a thunder-ſtorm, there is a contemporaneous accumulation and deficiency of the electric fluid, or that there are two parts in the atmoſphere, that are in the oppoſite ſtates of poſitive and negative electricity. Hence we may eaſily conceive the nature of the exploſion; for when the accumulation and deficiency, on the oppoſite ſurfaces of the ſtratum of air, have attained a certain height, a diſcharge muſt take place, ſimilar to the ſpontaneous diſcharge of a Leyden phial.

452 Generally confined to the heavens.

The exploſion commonly takes place in the heavens, and is merely the reſtoration of the equilibrium between oppoſite clouds; but in ſome inſtances, the exploſion happens between the clouds and the earth. In this latter caſe, it is believed by moſt electricians, that the earth is in the negative ſtate; but Mr G. Morgan is of opinion, that the deficiency is never in the earth, but in ſome other cloud to which an eaſier paſſage is found through ſo good a conductor as the wet earth, than through the air, which is an imperfect conductor. Mr Morgan brings a great many arguments in ſupport of his opinion, but for theſe we muſt refer to his lectures. It is of little conſequence to our preſent purpoſe, whether the deficiency is in the earth or in ſome adjacent cloud; it is ſufficient to know, that lightning ſometimes ſtrikes from the cloud to the earth, or from the earth to the clouds. When this happens, and when the accumulated fluid comes in contact with any body that is an imperfect conductor, ſuch as trees, buildings, &c. it produces thoſe devaſtations which are ſometimes the attendants of ſevere thunder-ſtorms; theſe, therefore, we are now to conſider.

453 Effects produced by lightning on a building.

Lightning, when it ſtrikes a building, for the moſt part attacks the higheſt parts of it, as the chimneys, or ſpires, eſpecially if theſe are ſurmounted by any metallic work, which is always the caſe with ſpires of churches, and not unfrequently on chimney-tops, where iron machines have been placed to prevent ſmoking. In moſt of the caſes which have been recorded of houſes being damaged by lightning, it has entered by the chimney, down which it ſeems to be conducted by the ſmoke and ſoot. Having entered the houſe, it commonly proceeds to the beſt and neareſt conductors in its paſſage, particularly bell-wires, gilt cornices, frames of pictures, and other gilded furniture; theſe it commonly deſtroys, fuſing, and very often oxidating, the metal as it paſſes along. Some very remarkable inſtances are related of the power of lightning in fuſing metals; we have heard of the fuſion of bells, of large chains, and of iron conducting-rods near an inch in diameter; but the authority on which theſe facts are related does not ſeem worthy of our implicit confidence. There are inſtances, however, ſufficiently credible, where the pointed end of a conductor has been rounded, parts of leaden ſpouts melted, and the edge and point of a knife completely fuſed. But in general the bell wires of a houſe ſuffer the moſt; theſe are always ſhortened and very commonly melted in ſome parts; while in others, they are entirely diſſipated in oxide, marks of which are very commonly viſible on the walls.

454 Fuſion of metals by lightning not a cold fuſion.

It has been diſputed, whether the fuſion of metals by lightning be ſuch a chemical fuſion as is occaſioned by fire, or what is called a *cold fuſion*. Dr Franklin was of the latter opinion; the principal arguments for which, are, that money has been melted in a perſon's pocket, and a ſword within its ſcabbard, without the pocket or the ſcabbard being deſtroyed. We confeſs ourſelves at a loſs to conceive what is meant by a *cold fuſion*, as we have no idea of a metallic body being fuſed at all, i. e. reduced into thoſe globular forms which metals that have been ſubjected to the action of lightning and electricity uſually aſſume, but by the power of a degree of heat, which would, when applied to bodies ſufficiently inflammable, ſet theſe on fire.

455 Lightning ſets fire to inflammable bodies.

That the exploſion of lightning frequently does this, is ſufficiently certain. In the ordinary caſes, indeed, of a building's being ſtruck by lightning, inflammation does not enſue, becauſe the parts of the building through which the fluid paſſes, are either in their nature very little inflammable, or are ſo hard and denſe in their texture, that they are not eaſily inflamed. But when the building attacked contains matters of a very combuſtible nature, ſuch as hay, ſtraw, and more eſpecially gun-powder, a fire is very commonly the conſequence; and accordingly, we every now and then hear of inſtances of ſtables being burned, and powder magazines blown up by lightning.

456 Tears ſuch bodies as reſiſt its paſſage.

When the lightning in its courſe meets with any obſtruction, as in paſſing through a body which is an imperfect conductor, it overcomes this obſtruction by forcing a paſſage through the reſiſting body: hence, we very commonly find large beams ſhattered, and ſtones and bricks either driven from their places, or ſplit and perforated in an unequal manner. Frequently, the lightning will forſake one conducting body, as the handle of a bell-wire, and ſtrike through the wall of the room, attracted by ſome conductor, either of greater power or larger dimenſions, ſuch as a kitchen grate, on the other ſide. This effect of lightning is exactly ſimilar to the perforation and rending of bodies by electricity, as we related when treating of the mechanical effects of that power; it is undoubtedly owing to the ſudden expanſion of of the air or moiſture contained within the pores of the reſiſting body.

457 Deſtroys animals life.

We have ſeen that animals are deſtroyed by lightning; but the effects of this power on the animal body come to be explained with more propriety in a future part of this work, where we ſhall treat of the effects of electricity on vegetable and animal life.

458 Death of Profeſſor Richman by lightning.

We ſhall here only relate the unfortunate death of the celebrated Profeſſor Richman of St Peterſburgh. This happened on the 6th of Auguſt 1753, as he was making experiments on lightning drawn into his own room. He had provided himſelf with an inſtrument for meaſuring the quantity of electricity communicated to his apparatus; and as he ſtood with his head inclined to it, Mr Solokow an engraver, who was near him, obſerved a globe of blue fire, as big as his fiſt, jump from the inſtrument, which was about a foot diſtant, to Mr Richman's head. The profeſſor was inſtantly dead, and Mr Solokow was alſo much hurt. The latter, however, could give no particular account of the way in which he was affected; for, at the time the profeſſor was ſtruck, there aroſe a ſort of ſteam or vapour, which entirely benumbed him, and made him ſink down to the ground, ſo that he could not even remember to have heard the clap of thunder, which was a very loud one. The globe of fire was attended with an exploſion like that of a piſtol; the inſtrument for meaſuring the electricity (called by the profeſſor an *electrical gnomon*) was broken to pieces, and the fragments thrown about the room. Upon examining the effects of the lightning in the profeſſor's chamber, they found the door-caſe half ſplit through, and the door torn off and thrown into the room. They opened a vein in the body twice, but no blood followed; after which, they endeavoured to recover life by violent friction, but in vain: upon turning the corpſe with the face downwards during the rubbing, an inconſiderable quantity of blood ran out of the mouth. There appeared a red ſpot on the forehead, from which ſpirted ſome drops of blood through the pores without wounding the ſkin. The ſhoe belonging to the left foot was burſt open, and uncovering the foot at that part, they found a blue mark; from whence it was concluded, that the electric matter having entered at the head, made its way out again at that foot. Upon the body, particularly on the left ſide, were ſeveral red and blue ſpots, reſembling leather ſhrunk by being burnt. Many more alſo became viſible over the whole body, and particularly over the back. That upon the forehead changed to a browniſh red, but the hair of the head was not ſinged. In the place where the ſhoe was unripped, the ſtocking was entire; as was the coat everywhere, the waiſtcoat only being ſinged on the fore flap where it joined the hinder: but there appeared on the back of Mr Solokow's coat long narrow ſtreaks, as if red-hot wires had burned off the nap, and which could not well be accounted for.

When the profeſſor's body was opened next day, the cranium was very entire, having neither fiſſure nor contra-fiſſure: the brain was ſound; but the tranſparent pellicles of the windpipe were exceſſively tender, and eaſily rent. There was ſome extravaſated blood in it, as alſo in the cavities below the lungs. Thoſe of the breaſt were quite ſound; but thoſe towards the back of a browniſh black colour, and filled with more of the blood above mentioned. The throat, the glands, and the ſmall inteſtines, were all inflamed. The ſinged leather-coloured ſpots penetrated the ſkin only. In 48 hours the body was ſo much corrupted, that they could ſcarcely get it into a coffin,

459 Diſtance at which the exploſion may be dangerous.

From the dangers to which perſons and buildings are expoſed from lightning, it becomes an object of importance to aſcertain the diſtance at which they may be conſidered as ſecure from its influence. The following obſervations of Mr G. Morgan on this ſubject are replete with ingenuity and good ſenſe.

460 Morgan's obſervations.

"The greateſt danger of a thunder-ſtorm lies between the two neareſt extremities of the correſpondent parts of the charged atmoſphere, or in that interval of unelectrified air which is always found to ſeparate the poſitive from the negative portion of the loaded cloud: but on either ſide of this interval, the further you get into the poſitive or the negative, the more does the power of injuring diminiſh.

"The idea which I now wiſh to impreſs, will be illuſtrated by the following circumſtances of fact.

"Take a Leyden phial, five inches in diameter, and thirteen or fourteen inches in height. On the inſide, let the coating riſe till its upper edge be two inches and a half from the rim of the veſſel. On the outſide, let the coating riſe no higher than one inch from the bottom. When the phial is thus coated, let it be charged, and a ſpark will paſs from the tin-foil on the outſide to that on the inſide; but its form will reſemble that of a tree, whoſe trunk will increaſe in magnitude and brilliancy, and conſequently in power, as it approaches the edge, owing to ramifications which it collects from all parts of the glaſs. Within two inches of the edge it becomes one body or ſtream, and along that interval its greateſt force acts.

"When two clouds, or the two correſpondent parts of a cloud, have their equilibrium reſtored by a diſcharge, the appearances are exactly ſimilar to thoſe of the preceding experiment. Each extremity of the flaſh is formed by a multitude of little ſtreams, which gather into one body, whoſe power is undivided in that interval only which ſeparates the poſitive from the negative.

"In this country theſe appearances are frequently ſeen; but they are moſt commonly hidden by intervening clouds. While I was paſſing over Mount Jura, one night during a thunder-ſtorm, the flaſhes ſucceeded each other ſo rapidly, that about thirty ſtruck within each minute, but owing to the height of my ſituation at that time, not one of them appeared otherwiſe than partially or generally, according to the deſcription I have juſt given. Sometimes a lower cloud would hide one of the two charged parts, and in this caſe the lightning aſſumed the form of a tree, whoſe trunk and branches only appeared. Sometimes the trunk was hidden, and then the ramifications on each ſide were alone viſible. Frequently intervening clouds would hide all but the trunk, and the lightning then appeared as it commonly does to a ſpectator in a low ſituation.

"It muſt be obvious from the preceding ſtatement of circumſtances, that the greateſt devaſtation of lightning muſt take place in that interval through which the whole body of the fluid paſſes, and that as you penetrate further and further into the cloud, the ſtream that is formed becomes leſs and leſs, like a river which diminiſhes

niſhes by entwiſting itſelf as you approach its fountain. Hence to us placed on the ground, no danger can ever occur, till the clouds are ſo low, that the ſtriking diſtance through air, or the aerial interval between the charged parts, reſiſts the paſſage more powerfully than the body of earth, and any additional portion of atmoſphere which may lie in the direction of the earth from the ſtriking interval.

"If the charged cloud lies in contact with the ground, its paſſage to the earth will be that of ſeveral ſtreams, and the danger will be great, in proportion to the magnitude of that ſeparate ſtream which paſſes through any given part of the earth; and ſeveral diſtinct ſituations may be thus unequally endangered at the ſame time. Hence it happens, that the ſame ſtroke will frequently injure ſeveral diſtinct buildings, which are very near to each other, and that different degrees of injury are always obſerved in the different tracts.

"The ſtriking diſtance, or the length of the interval of greateſt danger, will vary with the height of the charge, and not with the dimenſions of the charged body. This is clear from a multitude of facts already illuſtrated and applied. We may hence ſafely conclude, that the longer any charged cloud is in the vicinity of the wet ground, the more will the length, and conſequently the danger, of its ſtriking diſtance be diminiſhed, provided the points and prominences, which are active on the ground, diſcharge the fluid more abundantly than it is accumulated by the producing cauſe.

"From what I have already ſaid, it is clear that all the parts of the circuit, through which a thunder cloud may diſcharge its contents, are not equally dangerous, and that the maximum of danger is confined within much narrower limits than thoſe of the interval, within which it may be felt in one inferior degree or another. You muſt however perceive, that as the cloud enlarges, the number of additions increaſes, by which the great body of the flaſh is formed, and that the length of the moſt dangerous interval will always increaſe with, and bear a certain proportion to, the diameter of the cloud. In our attempts to eſtimate this diameter, we may follow two methods, which have been recommended; but I cannot ſay that either of theſe methods has any great pretenſions to accuracy.

"1ſt, If you meaſure the ſpace on which the thunder-ſhower falls, it is ſaid that you meaſure what is commenſurable with the dimenſions of the thunder-cloud. In a mountainous country this meaſurement is very poſſible; for the body of the ſhower may be ſeen at a ſmall diſtance, well deſcribed upon the elevated grounds whoſe parts it ſeparates from the eye. Its diameter, therefore, may be correctly eſtimated from the diſtance of thoſe well known objects by which it is bounded. Thoſe thunder-ſhowers, which I have obſerved, have varied in their diameter, from five hundred yards to two miles. It is, however, to be obſerved, that the partial vacuum, produced by the collapſe attending the removal of the electric fluid, may extend its influence to a greater diſtance, and cauſe the fall of rain, by rarefying the atmoſphere, far beyond the bounds of the charged cloud.

"2dly, The velocity of a cloud may be known by meaſuring its height, and the time which any fixed appearance in it takes to deſcribe a certain angle. This may be done in a very ſmall portion of time, and when it is done, you are next to watch the moment at which it begins to affect your elevated conductor, and with equal accuracy you are to mark the evaneſcence of its ſigns. The knowledge of theſe circumſtances, united with that of the cloud's velocity, will correctly determine its dimenſions.

"From a diary in my poſſeſſion, made by Mr Brook, it does not appear that the ſame electricity ever laſted more than fifteen minutes. When the ſymptoms of approaching thunder were deciſive, the oppoſite electricity generally laſted as long, and the interval of time between the two electrics ſeldom exceeded one-tenth of the whole.

"If we allow, that the cloud in this caſe moved at the rate of eight or ten miles in an hour, its diameter muſt have been four miles. However, in many inſtances, all the above-mentioned changes of electricity took place in two minutes. This happened ſeveral times ſucceſſively, and each ſeries of changes terminated by a flaſh of lightning. In all inſtances of this kind, to make the diameter of the cloud half a mile, we muſt ſuppoſe that it moves at the rate of thirty miles an hour; and in ſuch a caſe, one-tenth of the whole, or the interval of greateſt danger, would not exceed a hundred and eighty yards. But on the ſuppoſition that the ſize of the cloud were ſuch as to ſtrike over the diſtance of two miles, many are the circumſtances which, on its deſcent towards the ground will encroach upon its offenſive powers, change its direction, or decreaſe and perhaps altogether annihilate its violence.

"1. Innumerable points and prominences riſe from the whole ſurface of the earth over which it hangs. Theſe act as ſo many channels, through which its contents will find a rapid evacuation. In the power of carrying off the fluid gradually, I have been able to diſcover but little difference between partial and metallic conductors. It ſhould be added, that the torrent through an elevated wire is ſuch, when the cloud approaches it, as would diſcharge a battery, whoſe ſurface equalled four or five acres, in twenty or thirty ſeconds. When, therefore, millions of other conductors are acting with equal effect at the ſame moment, that muſt be an immenſe cloud indeed, whoſe ſtriking diſtance in ſuch circumſtances is not much leſſened, or whoſe ſtriking powers are not altogether exhauſted.

"2. Metals alone conduct the fluid better than charged ſurfaces. If a plate of glaſs, coated on one ſide with tin-foil, be charged and placed in a circuit, ſo that the contents of a jar may paſs over the other ſide uncoated, the luminous ſtriking diſtance will be quadruple what it is in air. Such a combination of changes as that which I have now deſcribed muſt frequently occur in the upper regions of the atmoſphere; for the charged clouds muſt lie in ſtrata above each other; and in the varieties of their motions, produced by their mutual attractions, and by the innumerable cauſes which affect their different currents, they muſt be perpetually ſerving as diſcharging-rods to one another. We conſequently find that nine hundred and ninety-nine flaſhes out of a thouſand, ſtrike from cloud to cloud through the intervening air*."

Severe ſhocks have been ſometimes experienced from

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*Morgan's *Lectures*, vol. ii.

a flaſh of lightning, when the perſon or building ſtruck has been at a very conſiderable diſtance from the cloud in which the diſcharge appeared to take place.

461 Danger from diſtant thunder.

A perſon at Vienna received a terrible ſhock from a thunder-rod, on which his hand reſted during an exploſion that happened at the diſtance of three miles from the place where the conductor was erected; and it is ſuppoſed that a ſhock might be felt, or even a perſon killed, at a diſtance "prodigiouſly greater." It is certain that during a thunder-ſtorm, the inſulated conductor is affected at every exploſion, however great, ſo as to emit ſparks.

It is ſuppoſed by moſt electricians that no *direct* ſtroke is adequate to the production of theſe effects, and they have therefore had recourſe to what Lord Stanhope calls the *returning ſtroke*. The following is an abridgement of this theory.

462 Lord Stanhope's theory of the returning ſtroke.

Let PC, fig. 122. repreſent a conductor charged poſitively; and AB a conductor in its natural ſtate, placed ſo that one of its extremities A, may juſt enter the atmoſphere of PC. In this caſe, Lord Stanhope ſays, that the ſuperabundance of PC will cauſe ſome of the natural ſhare of AB to paſs from A to B, where it is ſtopped and accumulated. By this change A is left in a different or negative ſtate, and B by the addition it has received becomes poſitive. But when the ſuperabundance at P is taken off, the poſitive fluid at B ruſhes back to its natural place at A, and this reſtoration is called the *returning ſtroke*.

Again, let us ſuppoſe PC to be *negative;* and A placed as before juſt within its atmoſphere. Now part of the fluid in AB will ruſh from B to A, and there being ſtopped will produce an accumulation; but when PC is diſcharged, this accumulation will diſappear, and the returning ſtroke will be from A to B *.

To apply this to the preſent caſe. Let us ſuppoſe two clouds horizontally diſtant, A and B (in the annexed diagram), the one A electrified poſitively and the other B negatively, to be incumbent over the ſurface of the earth at *a* and *b*; they will here tend to produce the oppoſite ſtates, or the part of the ſurface *a* will be *negative* and *b* *poſitive*. If now a diſcharge take place between the clouds A and B, the fluid will ruſh back from *b* to *a*; and if conductors are fixed at theſe places, the fluid will ruſh down the conductors at *b*, and up that at *a*. The ſame effects, though in a leſs degree, will be produced, if we ſuppoſe the negative cloud B placed *above* the poſitive cloud A. By this theory, Lord Stanhope undertook to explain how the man and two horſes were killed in the thunder-ſtorm deſcribed by Mr Brydone, and his Lordſhip preſented a very able paper on this ſubject to the Royal Society *.

A+ —B
a— +*b*

This theory of Lord Stanhope has been well received, and it is no ſmall teſtimony in its favour that it has obtained the ſupport of ſo able a philoſopher as Profeſſor Robiſon. Mr G. Morgan, however, ſtrenuouſly objects to this theory, on the very ſerious grounds that its *principle* is *erroneous*, its *effects overrated*, and its *application unneceſſary* †. Our limits will not permit us to detail all Mr Morgan's objections, but we muſt confeſs they do not convince us of the *fallacy* of the theory, although they certainly tend to invalidate the *effects* attributed to the returning ſtroke.

463 Effects of the returning ſtroke overrated.

"" Let us allow, (ſays Mr Morgan), that the force required by the theory is rendered active in the manner which I have juſt deſcribed, what reaſon have we for believing that it would be active to the *degree ſuppoſed?* Lord Stanhope has eſtimated, that what is ſeparated from our natural ſhare *without injuring us*, and what may be *abſent for hours without being felt*, is ſo great in quantity as to deſtroy us by its motion in returning. But what are the grounds of this eſtimate? As yet it has been juſtified by no appeal, either to fact or experiment; and the perſon who could ſay, that the greateſt poſſible loſs from our natural ſhare is little or nothing, would certainly ſtand upon equal, I think rather better, grounds, than thoſe who would make it adequate to the fuſion of metals and the deſtruction of life. I would add, that when the power of the returning ſtroke is magnified as it is in this theory, the *rationale* of this bold eſtimate is not only neglected, but it is neglected where it might have been made without much trouble.

"If the returning ſtroke of a thunder-cloud will deſtroy large edifices, ſurely artificial electricity could produce a ſimilar ſtroke which would deſtroy a bird or a mouſe, or act on ſome ſcale analogous to that which it is ſaid to reſemble. If, I ſay, the returning ſtroke in nature will melt the irons of a waggon wheel, ſurely, with the grand machines which we are now able to conſtruct, ſuch a returning ſtroke might be cauſed as would melt a capillary thread of metal. But nothing of this kind has ever been done or attempted by thoſe who ſupport the theory, and I am bold enough to prophecy, from the details of my own experience, that nothing of the kind ever will be done. ‡"

Sect. III. *Of the means of preventing Accidents from Lightning.*

464 Invention of conductors againſt lightning by Dr Franklin.

It has been well obſerved, that knowledge is valuable chiefly in proportion as it is uſeful; a maxim which no man ever exemplified better than Dr Franklin. No ſooner was the real nature of lightning aſcertained by experiment, than it was naturally ſuggeſted that this grand diſcovery might be rendered beneficial to mankind, by affording means for preſerving buildings from the formerly inevitable devaſtations of that powerful inſtrument of nature. Here too, the genius of Franklin led the way; and as he certainly deſerves the greateſt ſhare of the merit due to the diſcovery of the identity of lightning and electricity, we are alſo chiefly indebted to him for the means of applying this knowledge to advantage. He was led to propoſe the uſe of pointed metallic conductors attached to the building, as a ſecurity againſt the effects of lightning; and this propoſal, like moſt of Dr Franklin's ingenious contrivances in electricity, was the reſult at once of acute reaſoning and accurate obſervation.

465 His directions for their conſtruction.

Dr Franklin conſidered the earth as performing the office of a conductor, in reſtoring to the atmoſphere the electrical equilibrium, that had been diſturbed by the cauſes which tend to produce atmoſpherical electricity. In its courſe, he obſerves, that the lightning will commonly ſtrike the beſt conductors; and accordingly, as a metallic rod is a much more perfect conductor than the ſtones, bricks, &c. of which buildings are chiefly compoſed, the lightning will ſtrike the rod in prefer-

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* *Mahon's Principles of Electricity*, p. vii.

* *Phil. Tranſ.* vol. lxxvii.

† *Morgan's Lectures*, vol. ii. p. 171.

‡ *Morgan ubi ſupra*, p. 279.

ence to the materials of the building. He therefore adviſed, that a metallic rod ſhould be fixed to ſome part of the building, penetrating for ſome diſtance into the moiſt earth, and, as lightning does not in every caſe ſtrike the higheſt parts of a building, that the rod ſhould extend for ſome feet above theſe, in order, as it were, to ſolicit the lightning. As lightning has been found to deſtroy metallic rods of a conſiderable diameter, he adviſes, that theſe conductors ſhould be at leaſt half an inch thick, that they may the better reſiſt the deſtructive power of the lightning.

466 Requiſites to be obſerved.

From a compariſon of numerous experiments and obſervations, the following rules have been laid down for the conſtruction of conductors.

467 Should be of the beat conductors.

1. *That the rods be made of ſuch ſubſtances as are in their nature the beſt conductors of electricity.*

It is found that all metals do not conduct equally well, and that *lead* and *copper* are the beſt fitted to ſerve as conductors againſt lightning; but as lead is exceedingly deſtructible by electricity, and therefore would require to be of a very conſiderable diameter, *copper* is to be preferred, as well on account of its greater conducting power, as from its being leſs liable to contract ruſt than *iron*, which is commonly employed.

468 Should be of ſufficient diameters, and

2. *That the rods be of a ſufficient diameter.*

469 Perfectly continuous.

3. *That they be perfectly uninterrupted, or, if formed of ſeveral pieces, that their junctions be as nearly in contact as poſſible.*

The effect of interruptions in conductors, as well as the effects of lightning in general on buildings, may be illuſtrated by the following experiments.

470 Thunder-houſe.

Exper. 1.—Fig. 123. ſhews an inſtrument repreſenting the ſide of a houſe, either furniſhed with a metallic conductor, or not; by which both the bad effects of lightning ſtriking upon a houſe not properly ſecured, and the uſefulneſs of metallic conductors, may be clearly repreſented. A is a board about three-quarters of an inch thick, and ſhaped like the gable end of a houſe. This board is fixed perpendicularly upon the bottom board B, upon which the perpendicular glaſs pillar CD is alſo fixed, in a hole about eight inches diſtant from the baſis of the board A. A ſquare hole, ILMK, about a quarter of an inch deep, and nearly one inch wide, is made in the board A, and is filled with a ſquare piece of wood, nearly of the ſame dimenſions. We ſay nearly of the ſame dimenſions, becauſe it muſt go ſo eaſily into the hole, that it may drop off by the leaſt ſhaking of the inſtrument. A wire, LK, is faſtened diagonally to this ſquare piece of wood. Another wire, IH, of the ſame thickneſs, having a braſs ball, H, ſcrewed on its pointed extremity, is faſtened upon the board A; ſo alſo is the wire MN, which is ſhaped in a ring at O. From the upper extremity of the glaſs pillar CD, a crooked wire proceeds, having a ſpring ſocket F, through which a double-knobbed wire ſlips perpendicularly, the lower knob G of which falls juſt above the knob H. The glaſs pillar DC muſt not be made very faſt into the bottom board; but it muſt be fixed ſo as to be pretty eaſily moved round its own axis, by which means the braſs ball G may be brought nearer or farther from the ball H, without touching the part of EFG. Now when the ſquare piece of wood LMIK (which may repreſent the ſhutter of a window or the like) is fixed into the hole ſo, that the wire LK ſtands in the dotted repreſentation IM, then the metallic communication from H to O is complete, and the inſtrument repreſents a houſe furniſhed with a proper metallic conductor; but if the ſquare piece of wood LMIK is fixed ſo, that the wire LK ſtands in the direction LK, as repreſented in the figure, then the metallic conductor HO, from the top of the houſe to its bottom, is interrupted at IM, in which caſe the houſe is not properly ſecured.

Fix the piece of wood LMIK, ſo that its wire may be as repreſented in the figure, in which caſe the metallic conductor HO is diſcontinued. Let the ball G be fixed at about half an inch perpendicular diſtance from the ball H, then, by turning the glaſs pillar DC, remove the former ball from the latter: by a wire or chain connect the wire EF with the wire Q of the jar P, and let another wire or chain, faſtened to the hook O, touch the outſide coating of the jar. Connect the wire Q with the prime conductor, and charge the jar; then, by turning the glaſs pillar DC, let the ball G come gradually near the ball H, and when they are arrived ſufficiently near one another, you will obſerve that the jar explodes, and the piece of wood, LMIK, is puſhed out of the hole to a conſiderable diſtance from the thunder-houſe. Now the ball G, in this experiment, repreſents an electrified cloud; which, when it is arrived ſufficiently near the top of the houſe A, the electricity ſtrikes it, and, as this houſe is not ſecured with a proper conductor, the exploſion breaks part of it, i. e. knocks off the piece of wood IM.

Repeat the experiment with only this variation, viz. that this piece of wood IM is ſituated ſo, that the wire LK may ſtand in the ſituation IM; in which caſe the conductor HO is not diſcontinued; and you will obſerve, that the exploſion will have no effect upon the piece of wood LM; this remaining in the hole unmoved; which ſhews the uſefulneſs of the metallic conductor.

Further: Unſcrew the braſs ball H from the wire HI, ſo that this may remain pointed, and, with this difference only in the apparatus, repeat both the above experiments; and you will find that the piece of wood IM is in neither caſe moved from its place, nor any exploſion will be heard; which demonſtrates the preference of conductors with pointed terminations to thoſe with blunted ones.

471 Powder-houſe.

Exper. 2.—This apparatus is ſometimes made in the ſhape of a houſe, as repreſented fig. 124. where, for the ſake of diſtinctneſs, the ſide and part of the roof next the eye are not repreſented. The gable end AC repreſents that of the thunder-houſe, and may be uſed in the ſame manner with that above deſcribed, or more readily by the following method. Let one ball of the diſcharging rod touch the ball of the charged jar, and the other the knob A of the conductor AC of the thunder-houſe; the jar will then of courſe explode, and the fluid will act upon the conductor juſt mentioned. The conducting wire at the windows *h h* muſt be placed in a line. The ſides and gable AC of the houſe are connected with the bottom by hinges; and the building is kept together by a ridge on the roof. To uſe this model, fill the ſmall tube *a* with gunpowder, and ram the wire *c* a little way into the tube; then connect the tube *e* with the bottom of a large jar or battery. When the jar is charged, form a communication from the hook at C, on the outſide, to the top of the jar, by diſcharging the rod; the diſcharge will fire the powder, and the exploſion of the latter will throw off the roof, with the ſides, back and front, ſo that they will all fall down together. The figures *f* and *g* in the ſide of the houſe repreſent a ſmall ramrod for the tube *a*, and a pricker for the touch-hole at C.

Mr Jones of Holborn makes the front of the common thunder-houſes, as well as the powder-houſe above deſcribed, with two pieces of wood or windows *h h*, which, by being placed in proper ſituations, the one to conduct and the other to reſiſt the fluid, will illuſtrate by one diſcharge the uſefulneſs of good conductors for ſecuring buildings or magazines from the exploſion of thunder, as well as the danger of uſing imperfect ones.

472 Effects of breaks in conductors, illuſtrated by a pyramid.

Exper. 3.—Fig. 125. repreſents a wooden pyramid, made in ſeveral pieces, with a wire through each, ſo that their ends may touch, as at *s s s*. Let one corner of the pedeſtal *d* be looſe, and have the ſafety wire paſs almoſt but not quite through it. Let the wire paſſing through the reſt of the pedeſtal join by a chain the outſide coating of a Leyden phial. If the cloud *x* be ſupported by a wire from the prime conductor, and hang half an inch from the knob *q* of the pyramid; when the phial is diſcharged, a flaſh will take place between *x* and *g*; the ſpark will paſs along the wires *s s s*, till it comes to the break at *d*; there an exploſion will take place, that will drive out the corner-ſtone *d*, and overthrow the fabric.

Abundant obſervation has proved the danger of having diſcontinuous conductors either attached to a building, or forming part of the materials. About the middle of the laſt century, the ſteeple of St Bride's church in London was ſtruck by lightning, and greatly injured. In the conſtruction of this ſteeple a great deal of iron work had been employed; the ſtones having been faſtened together in many places by iron cramps, the ends of which were covered with ſmall ſtones. The lightning ſeems firſt to have ſtruck the vane of the ſpire, from which it was ſafely conducted down the ſhaft by which the vane was ſupported; from the extremity of this ſhaft, it leaped to two croſs iron bars which were at the baſe of the obeliſk, ſhattering the obeliſk in its way. Hence it paſſed to one of the above mentioned cramps, and thus from cramp to cramp throwing out or demoliſhing the ſtones as it paſſed along.

473 Effect of an interruption explained.

The principles of electricity afford us an eaſy explanation of the manner in which the interruption of conductors acts. We know that at the extremity of all long rods there is a conſiderable accumulation of electricity, and this has here a tendency to fly off with great force, eſpecially if there is another conductor at hand. This other conductor alſo aſſiſts the accumulation in the former by acquiring at its adjacent extremity the oppoſite electricity. Suppoſing a poſitive cloud to be over the upper conductor, this conductor will be electrified poſitively at its lower extremity, and this accumulation being increaſed by the negative electricity of the upper and of the lower conductor, will tend to fly off with great violence into the air, or if any obſtruction oppoſe its paſſage, this will be removed by the burſting or diſplacing the reſiſting body.

474 Should be properly connected with the earth.

4. *It is neceſſary that the connection between the conductor and the common ſtock, or the earth, be as complete as poſſible.*

It has been ſaid, that the lower extremity of the conductor ſhould be inſerted ſome feet below the ſurface of the ground: it is alſo proper that it ſhould be turned in a direction away from the foundation; and as moiſture is one of the beſt conductors, it would be adviſeable, where this can conveniently be done, to connect the extremity of the metallic rod with ſome neighbouring piece of water.

475 Should be as ſtrait as poſſible.

5. *That the rod be carried from the top of the building to the common ſtock in the ſhorteſt convenient direction.*

6. *That the upper extremity be finely tapered, and terminate in a ſharp ſmooth point.*

476 Should be pointed.

There is no queſtion in electricity, that has been argued with more keenneſs, than whether thunder-rods ſhould terminate in a ſharp point, or in a round ball. Dr Franklin, we have ſeen, decidedly gave the preference to a pointed conductor, and he has been followed by moſt of the electricians of Europe; Dr Wilſon ſtanding almoſt alone in ſupport of the round ball. This controverſy was renewed with great warmth on the occaſion of a houſe at Purfleet belonging to the board of ordnance, having been ſtruck by lightning, although guarded by a pointed conductor. A ſet of very ingenious experiments were made, both by Mr Nairne and Dr Wilſon, to eſtimate the comparative merits of pointed and obtuſe conductors; but by theſe the queſtion was not decided; Mr Nairne's experiments always concluding in favour of pointed conductors, while thoſe of Dr Wilſon as conſtantly favoured the obtuſe termination. Moſt electricians, however, ſtill prefer the pointed conductor.

Let B (fig. 126.) repreſent the poſition of a charged cloud; A, the part that is oppoſitely charged, or that is connected with it; FG a pointed wire. In this caſe, the electric fluid muſt paſs either through the ſeries of partial conductors, *a*, *b*, *c*, &c. or through the body of earth, AF.

Now when, on the one hand, we conſider the dryneſs of that ſoil which is generally ſelected for the foundation of buildings, the probability there is that nothing but the ſoil, thus dry, may ſeparate A from the wire FG, and the certainty that if water ſhould connect A and FG, its reſiſtance is very conſiderable; when, on the other hand, we take into conſideration, the nails, bolts, iron bars, ſtrips of lead, bell wires, and metallic utenſils that are ſcattered through all buildings, we ſhall, I think, perceive the much greater probability there is of the lightning's paſſing through *a*, *b*, *c*, *d*, &c. to the cloud, than of its paſſage through the ground.

2. Let us erect another wire, HI, and ſtill the danger is almoſt as great; for now the poſſible circuits of the lightning are four, and of thoſe, that leading through the houſe appears to be the eaſieſt: if HI convey it harmleſs, then it muſt paſs through the body of the air FG, or over the roof of the houſe. We well know from paſt experiments, that the inſulating power of the air makes the reſiſtance in the direction IG very conſiderable; and even on the ſuppoſition that *j* were wet, the reſiſtance over the roof of the houſe is not much conſiderable. If the houſe were covered or coped with lead, the probability of a ſtroke would then be diminiſhed, but not taken away; for, ſuppoſe the eaſieſt circuit ſhould lie in the direction KM, then, rather than paſs through the body of earth HK, or FK, it might

might find an eaſier paſſage through the houſe than either of the conductors. This would not be the caſe, if a ſtrip of lead, or metallic ſubſtance of any kind, extended from K to H, and from K to F. "I hence thought, (ſays Mr Morgan), at one time, that a houſe would be perfectly ſafe, if a ſtrip of lead were carried around the top, and all the bottom of the building, and then connected by two or three metallic ſtrips extending from the one to the other.

"Let us ſuppoſe that a houſe were erected over a ſtratum of moiſture, or any other conducting ſubſtance, which dipped conſiderably, at a little diſtance from the houſe, and then ſuddenly roſe juſt below it; in that caſe, if the ſtratum became the circuit of a charge, the ſtroke would riſe immediately in the centre or body of the houſe, and in all directions would force its way with devaſtation, towards the conductors on the outſide."

477
Mr Morgan's propoſal for preventing all poſſible danger.

To prevent all poſſible danger, Mr G. Morgan propoſes, that, while the houſe is building, the foundation of each partition wall be laid on a ſtrip of lead, or that ſuch a ſtrip be faſtened to the ſides of theſe partition walls. The ſtrips ſhould be two inches wide, and at leaſt a quarter of an inch thick, and they ſhould be cloſely connected with each other. A perpendicular ſtrip on each ſide of the houſe, ſhould riſe from this bed of conductors, to the ſurface of the ground; whence a ſtrip ſhould be continued round all the houſe, and carefully connected with water-pipes, &c. The ſtrips on the ſides of the houſe, ſhould then be continued to the roof, which ſhould be guarded in the ſame manner as the foundation. The top ſhould be ſurrounded by a ſtrip, whoſe connection ſhould ſpread over every edge and prominence, and ſhould continue to the ſummit of each ſeparate chimney. It is particularly neceſſary to guard the chimnies; for Mr Morgan was witneſs to a caſe, in which a houſe that had been guarded, in moſt reſpects, according to the foregoing directions, except that the chimnies were unprotected, was ſtruck with lightning which entered by one of the chimnies: here it ſpent its fury; but the chimney falling on the roof, did conſiderable damage.

The principal objection to this method, is the expence attending it; but this may be, in a great meaſure avoided, by making proper uſe of the leaden pipes, gutters, and copings, which belong to moſt houſes.

478
Means of protecting ſhips.

Ships, from the height and conſtruction of their maſts, and from their being ſuch inſulated conducting objects as muſt neceſſarily attract the lightning from a cloud that is very near, are peculiarly expoſed to danger. It is, therefore, ſtill more neceſſary to guard veſſels by proper conductors. Chains are very commonly employed for this purpoſe, from their being more conveniently diſpoſed among the rigging; but it is found, that from the want of continuity in the links, chains are very imperfect conductors, and have not unfrequently been broken by a ſevere ſhock. Strips of lead, are therefore, to be preferred, both as they are cheaper, and leſs liable to be injured by the weather and ſalt water, than iron chains. One ſtrip ſhould ſurround the deck, and another the bottom or ſide of the keel, and theſe ſhould be connected with other ſtrips, embracing the ſhip in various parts. If the ſhip be copper-bottomed, it will only be neceſſary to connect the copper with the deck; but in every caſe, a ſtrip ſhould paſs on each ſide from the reſt of the ſtrips to each maſt. The maſt may be protected by extending a metallic body along the ſtays to as great a height as poſſible, and connecting this with the top of the maſt, and with the reſt of the conductors ſurrounding the ſhip.

479
Means of preventing perſonal danger.

The principles of electricity, applied to the explanation of the phenomena of lightning, alſo afford us ſome uſeful hints for our perſonal ſecurity during a thunder-ſtorm. Theſe naturally divide themſelves into two heads, firſt, the conſideration of the ſigns of approaching danger, and ſecondly, the rules to be obſerved, when we find ourſelves within the ſtriking diſtance of the cloud.

480
Signs of approaching danger.

1. Approaching danger may be dreaded from the following circumſtances.

a. *A rapid approach of the charged clouds.* The longer time any given portion of charged air remains over a certain ſpace, the more it is affected by points and prominences; but when a cloud ſeems to be over our heads almoſt as ſoon as it is formed, we are expoſed to the utmoſt of its fury. When a cloud grows darker and darker while it is near us, it is alſo a mark of great danger, for we may be certain the accumulation is not materially leſſened by an exhauſtion, and that the charge muſt ſoon attain its ſtriking height.

b. *The perpendicular direction of the flaſhes.* This is a certain evidence that the charged clouds are at that height from which they can ſtrike into the ground. The appearance of two flaſhes at the ſame time, has been conſidered as an evidence, that the earth is acting as a diſcharging rod; but this may often happen, as the two extremities of the flaſh, when paſſing behind a cloud which partly hides it, may often give out the ſame appearance; the ſign, therefore, is not ſufficiently accurate, and cannot be conſidered as denoting more than a certain degree of probable danger.

c. *In making experiments with the kite, if very ſtrong ſparks are emitted from the ſtring, or if a ſenſation like a cob-web paſſing over the face be felt, it is time to deſiſt.* This will be fully illuſtrated in the experiments which we are about to relate on atmoſpherical electricity.

d. *In making experiments with an inſulated conductor, if a torrent of ſparks ſhould flow from its interruptions, or if ſuch a torrent, after having continued for ſome time, ſhould ſuddenly ſtop, and ſoon after recommence with an oppoſite electricity, there is conſiderable danger in being near the conductor.*

2. Having aſcertained, that we are within the limits of danger, our next object is to ſeek protection; it is therefore neceſſary to know how the threatened danger may be avoided.

481
Rules for protection in various ſituations.

In a houſe, it is neceſſary to place one's ſelf at a diſtance from all good conductors, ſuch as chimney places, gilt mirrors or pictures, luſtres, or burning candles. It is therefore proper, to withdraw into the middle of a room, where no metallic body is ſuſpended from the ceiling, and here, according to Dr Franklin, almoſt all poſſible danger may be avoided, by bringing a bed or matraſs, and placing on it the chair on which we ſit.

If we are in the open air, and overtaken by a thunder-ſtorm, it is proper to avoid all high and pointed objects, except trees perhaps; but we muſt not come very near theſe, keeping only at ſuch a diſtance as may prevent our being injured by the ſplinters of wood, if the tree ſhould be ſtricken. It is particularly neceſſary to avoid rivers and brooks, as theſe are excellent conductors.

Perhaps the beſt protection in the open air, is a carriage made ſo large, as that a perſon may ſit in it at a diſtance from the ſides, eſpecially if it be ſurrounded at the top and bottom with metallic fillets connected with each other by a ſtrip of the ſame ſubſtance.

If overtaken in a ſtorm, it is ſafer to be completely wet than dry.

Chap. II. *Experiments and Obſervations on the Spontaneous Electricity of the Atmoſphere.*

482
Experiments on atmoſpherical electricity, by Monnier.

THE firſt perſon who obſerved the ſpontaneous electricity of the atmoſphere, was M. Monnier, who found that even when there was no appearance of lightning, ſome degree of electricity might generally be obſerved in the atmoſphere. His experiments were made at St Germaine en Laye, and publiſhed in a memoir read at the Royal Academy of Sciences at Paris in 1752.

483
Abbé Mazeas.

But more accurate experiments were made upon the electricity of the air by the abbé Mazeas, at Chateau de Maintenon, during the months, June, July, and October, of 1753, and communicated to the Royal Society in a letter to Dr Hales.

The abbé's apparatus conſiſted of an iron rod, 370 feet long, raiſed 90 feet above the horizon. It came down from a very high room in the caſtle, where it was faſtened to a ſilken cord ſix feet long; and was carried from thence to the ſteeple of the town, where it was likwiſe faſtened to another ſilken cord of eight feet long, and ſheltered from rain. From the extremity of this rod, a large key was ſuſpended to receive the electric fluid.

When he began his experiments, viz. on the 17th of June, the electricity of the air was ſenſibly felt every day, from ſunriſe till ſeven or eight in the evening, except in moiſt weather, when he could perceive no ſigns of electricity. In dry weather, the rod attracted minute bodies at no greater diſtance than three or four lines. He repeated the experiment carefully every day, and conſtantly obſerved, that in weather void of ſtorms, the electricity of a piece of ſealing wax of two inches long, was above twice as ſtrong as that of the air. This obſervation inclined him to conclude, that in weather of equal dryneſs, the electricity of the air was always equal.

It did not appear to him that hurricanes and tempeſts increaſed the electricity of the air, when they were not accompanied with thunder; for that during three days of a very violent continual wind in July, he was obliged to put ſome duſt within four or five lines of the conductor, before any ſenſible attraction could be perceived.

No ſenſible alteration in the electricity of the air was obſerved under different directions of the winds, except when theſe were moiſt.

He could obſerve no electricity in the air during the drieſt nights of ſummer, but it returned in the morning with the ſun, diſappearing again ſoon after ſunſet.

The ſtrongeſt common electricity of the atmoſphere during that ſummer, was obſerved in July, on a very dry, clear, warm day.

On the 27th of June about noon, he perceived ſome ſtormy clouds riſing above the horizon, and obſerved that the electricity of the atmoſphere occaſioned by them, was increaſed as the clouds reached the zenith. He at this time drew conſiderable ſparks from his apparatus, though there was neither thunder nor lightning.

The electricity obſerved during the appearance of theſe ſtormy clouds, was not diminiſhed by a very heavy rain, till the clouds began to diſſipate *.

484
Mr Kinnerſley.

Mr Kinnerſley obſerved, that when the air was in its drieſt ſtate, there was always a quantity of electricity in it, and which might be eaſily drawn from it. This, he ſays, may be proved by a perſon in the negative ſtate of electricity extending his arm into the air in the dark while holding a pointed needle in his hand; this, however, can only be obſerved when the air is very dry.

Whether the electricity in the air, in clear dry weather, be of the ſame denſity at the height of two or three hundred yards, as on the ſurface of the earth, Mr Kinnerſley thought might be eaſily aſcertained by Dr Franklin's old experiment with the kite. The twine, he ſays, ſhould have throughout a very ſmall wire in it, and the ends of the wire, where the ſeveral lengths are united, ought to be tied down with a waxed thread, to prevent their acting in the manner of points †.

485
Mr Canton.

Mr Canton made ſeveral ingenious experiments on atmoſpherical electricity, by means of his pith-ball electrometer, deſcribed in N° 66. According to this philoſopher, deſiccated atmoſpheric air, when heated, becomes negatively electric, and when cooled, the electricity is of the poſitive kind, even when the air is not permitted to expand or contract; and the expanſion or contraction of atmoſpheric air occaſions changes in its electrical ſtate ‡.

486
Beccaria.

But no electrician, in the earlier ſtage of the ſcience, conducted his obſervations in this way with greater accuracy, or purſued them farther than Sig. Beccaria. He obſerved, that, during very high winds, his apparatus gave no ſigns of being electrified. Indeed he found, that in three different ſtates of the atmoſphere, he could find no electricity in the air: viz. in windy and clear weather; in weather when the ſky was covered with diſtinct and black clouds, that had a ſlow motion; in moiſt weather, not actually raining. In a clear ſky, when the weather was calm, he always perceived ſigns of a moderate electricity, but interrupted. In rainy weather without lightning, his apparatus was always electrified a ſhort time before the rain fell, and during the time of the rain, but it ceaſed to be affected a little before the rain was over.

The higher his rods reached or his kites flew, the ſtronger ſigns they gave of electricity. Alſo longer ſtrings and cords, extended and inſulated in the open air, acquired electricity ſooner than thoſe which were ſhorter. A cord 1500 Paris feet long, ſtretched acroſs the river Po, was as ſtrongly electrified during a ſhower without thunder, as a metallic rod, employed to bring lightning into his houſe, had been in any thunderſtorm.

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* *Phil. Tranſ.* vol. xlviii.

† *Ibid.* vol. liii.

‡ *Ibid.* vols xlviii. and xlix.

Having two rods for bringing the lightning into his houſe, 140 feet aſunder, he obſerved, that if he took a ſpark from the higher of theſe, the ſpark from the other, which was 30 feet lower, was at that inſtant leſſened; but its power again revived, though he kept his hand upon the former.

He imagined that the electricity communicated to the air might ſometimes furniſh ſmall ſparks to his apparatus; ſince the air parts with the electricity it has received very ſlowly, and therefore the equilibrium of the electric fluid in the air, will not be reſtored ſo ſoon as in the earth and clouds.

487
Rain, hail, and ſnow, ſuppoſed effects of electricity.

Among the effects of a moderate electricity in the atmoſphere, Signior Beccaria conſiders rain, hail, and ſnow.

Clouds that bring rain, he thought, were produced in the ſame manner as thunder-clouds, only by a more moderate electricity.

He notes ſeveral circumſtances attending rain without lightning, which make it very probable, that it is produced by the ſame cauſe as when it is accompanied with lightning. Light has been ſeen among the clouds by night in rainy weather; and even by day, rainy clouds are ſometimes ſeen to have a brightneſs evidently independent of the ſun. The uniformity with which the clouds are ſpread, and with which the rain falls, he thought were evidences of a uniform cauſe, like that of electricity. The intenſity of electricity in his apparatus, generally correſponded very nearly to the quantity of rain that fell in the ſame time.

Sometimes all the phenomena of thunder, lightning, hail, rain, ſnow and wind, have been obſerved at one time; which ſhews the connection they all have with ſome common cauſe.

Signor Beccaria ſuppoſes, therefore, that previous to rain, a ſmall quantity of electric fluid eſcapes out of the earth, in ſome place where there was a redundancy of it; and in its aſcent to the higher regions of the air, collects and conducts into its path a great quantity of vapours. The ſame cauſe that collects will condenſe them more and more, till in the places of the neareſt intervals they come almoſt into contact, ſo as to form ſmall drops, which uniting with others as they fall, come down in rain. The rain will be heavier in proportion as the electricity is more vigorous, and the cloud approaches more nearly to a thunder cloud.

He imitated the appearance of clouds that bring rain, by inſulating himſelf between the rubber and conductor of his electrical machine, and with one hand dropping *colophonium* into a ſpoon faſtened to the conductor, and holding a burning coal, while his other hand communicated with the rubber. In theſe circumſtances, the ſmoke ſpread along his arm, and by degrees all over his body, till it came to the other hand that communicated with the rubber. The lower ſurface of this ſmoke was everywhere parallel to his clothes, and the upper ſurface was ſwelled and arched like clouds replete with thunder and rain. In this manner, he ſuppoſed, the clouds that bring rain diffuſe themſelves from over thoſe parts of the earth which abound with the electric fluid, to thoſe parts that are exhauſted of it; and by letting fall their rain, reſtore the equilibrium between them.

488
Beccaria's idea of the production of hail.

This ingenious philoſopher ſuppoſes hail to be formed in the higher regions of the air, where the cold is intenſe, and where the electric fluid is very copious. In theſe circumſtances a great number of particles of water are brought near together, where they are frozen, and in their deſcent collect other particles, ſo that the denſity of the ſubſtance of the hailſtone grows leſs and leſs from the centre; this being formed firſt in the higher region, and the ſurface being collected on the lower. Agreeable to this it is obſerved, that in mountains, hailſtones, as well as drops of rain, are very ſmall; there being but ſmall ſpace through which to fall and thereby increaſe their bulk. Drops of rain and hail alſo agree in this circumſtance, that the more intenſe is the electricity that forms them, the larger they are.

Clouds of ſnow differ in nothing from clouds of rain, but in the circumſtance of cold which freezes them. Both the regular diffuſion of ſnow, and the regularity in the ſtructure of its particles, ſhew the clouds of ſnow to be actuated by ſome uniform cauſe like electricity. All theſe conjectures about the cauſe of hail and ſnow were confirmed by obſerving, that his apparatus never failed to be electrified by ſnow, as well as by rain.

A more intenſe electricity unites the particles of hail more cloſely, than the more moderate electricity does thoſe of ſnow. In like manner, we ſee thunder clouds more denſe than thoſe that merely bring rain, and the drops of rain are larger in proportion, though they often fall not from ſo great a height *.

489
Obſervations by Mr Ronayna.

Mr Ronayne obſerved, that the air in Ireland was generally electrified in a fog, and even in a miſt, and that both day and night, but principally in winter; ſeldom in ſummer, except from poſitive clouds or cool fogs. The electricity of the air in a froſt or fog is always poſitive. He ſays, that he has often obſerved, during what ſeemed the paſſing of one cloud, ſucceſſive changes from negative to poſitive, and from poſitive to negative. It may be remarked that moſt fogs have a ſmell like an excited glaſs tube †.

490
By Mr Henley.

Mr Henly has ſhewn, that fogs are more ſtrongly electrified in or immediately after a froſt than at other times; and that the electricity of fogs is often the ſtrongeſt ſoon after their appearance. Whenever there appears a thick fog, and at the ſame time the air is ſharp and froſty, that fog is ſtrongly electrified poſitively.

Though rain is not an immediate cauſe, yet Mr Henly is inclined to conſider it as a remote conſequence of atmoſpherical electricity; and he generally found, that in two or three days after he had diſcovered the air to be ſtrongly electrified, there was either rain or ſnow.

If, in clear weather, a low cloud, which moves ſlowly and is conſiderably diſtant from any other, paſſes over the apparatus, the poſitive electricity generally grows very weak, but does not become negative; and when the cloud is gone, it returns to its former ſtate. When many whitiſh clouds keep over the wire, ſometimes uniting with and then ſeparating from each other, thus forming a body of conſiderable extent, the poſitive electricity commonly increaſes. In all the above circumſtances the poſitive electricity never changes to negative.

The clouds which leſſen the electricity of the exploring wire, are thoſe which move; though thoſe that are low, ſeem alſo to have the ſame effect.

491
By Mr Cavallo.

Mr Cavallo has conſiderably improved our knowledge with reſpect to atmoſpherical electricity, and by his apparatus, has greatly facilitated the means of

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* *Lett. dell' Elettriciſmo.*

† *Phil. Tranſ.* vol. lxii.

492 Conſtruction of his kite.

making experiments. His firſt experiments were made by means of a kite; and after beſtowing much pains in conſtructing kites of various dimenſions, &c. he found that a common ſchool-boy's kite, about four feet high, and two wide, anſwered as well as any other. The ſtring of his kite was formed by twiſting together two threads of common twine, and one of copper thread, ſuch as is uſed for trimmings. When a kite conſtructed in this manner was raiſed, he always found the ſtring give ſigns of electricity, except once, when the weather was warm, and the wind ſo very weak, that the kite could ſcarcely be raiſed, and could be kept up only for a few minutes. Afterwards, however, when the wind increaſed ſo that he could eaſily raiſe the kite, he obtained, as uſual, pretty ſtrong ſigns of electricity.

493 Means of avoiding danger.

As making experiments on atmoſpherical electricity is often attended with more or leſs danger, it is neceſſary to obſerve the following directions given by Mr Cavallo.

"In raiſing the kite when the weather is very cloudy and rainy, in which time there is fear of meeting with a great quantity of electricity, I generally uſe to hang upon the ſtring AB, fig. 127. the hook of a chain C, the other extremity of which falls upon the ground. Sometimes I uſe another caution beſides, which is, to ſtand upon an inſulating ſtool; in which ſituation I think, that if any great quantity of electricity, ſuddenly diſcharged by the clouds, ſtrikes the kite, it cannot much affect my perſon. As to inſulated reels, and ſuch-like inſtruments, that ſome gentlemen have uſed to raiſe the kite, without danger of receiving any ſhock; fit for the purpoſe as they may appear to be in theory, they are yet very inconvenient to be managed. Except the kite be raiſed in time of a thunder-ſtorm, there is no great danger for the operator to receive any ſhock. Although I have raiſed my electrical kite hundreds of times without any caution whatever, I have very ſeldom received a few exceedingly ſlight ſhocks in my arms. In time of a thunder-ſtorm, if the kite has not been raiſed before, I would not adviſe a perſon to raiſe it while the ſtormy clouds are juſt overhead; the danger at ſuch time being very great, even with the precautions above mentioned: at that time, without raiſing the kite, the electricity of the clouds may be obſerved by a cork-ball electrometer held in the hand in an open place; or, if it rains, by my electrometer for the rain; which will be deſcribed hereafter.

"When the kite has been raiſed, I generally introduce the ſtring through a window in a room of the houſe, and faſten it to a ſtrong ſilk lace, the extremity of which is generally tied to a heavy chair in the room. In fig. 128. AB repreſents part of the ſtring of the kite which comes within the room; C repreſents the ſilk lace; DE, a ſmall prime conductor, which, by means of a ſmall wire, is connected with the ſtring of the kite; and F repreſents the quadrant electrometer, fixed upon a ſtand of glaſs covered with ſealing-wax, which I uſed to put near the prime conductor, rather than to fix it in a hole upon the conductor, becauſe the ſtring AB ſometimes ſhakes ſo as to pull the prime conductor down; in which caſe the quadrant electrometer remains ſafe upon the table: otherwiſe it would be broken, as I have often experienced before I thought of this method. G repreſents a glaſs tube, about eighteen inches long, with a knobbed wire cemented to its extremity; with which inſtrument I uſe to obſerve the quality of the electricity, when the electricity of the kite is ſo ſtrong that I think it not ſafe to come very near the ſtring. The method is as follows:—I hold the inſtrument by that extremity of the glaſs tube which is the fartheſt from the wire, and touch the ſtring of the kite with the knob of its wire, which, being inſulated, acquires a ſmall quantity of electricity from it; which is ſufficient to aſcertain its quality when the knob of the inſtrument is brought near an electrified electrometer.

"Sometimes, when I raiſe the kite in the night-time, out of the houſe, and where I have not the convenience of obſerving the quality of its electricity by the attraction and repulſion, or even by the appearance of the electric light, I make uſe of a coated phial, which I can charge at the ſtring, and, when charged, put it into my pocket; wherein it will keep charged even for ſeveral hours. By making uſe of this inſtrument, I am obliged to keep the kite up no longer than is neceſſary to charge the phial, in order to obſerve the quality of the electricity in the atmoſphere; for after the kite has been drawn in and brought home, I can then examine the electricity of the inſide of the phial, which is the ſame as that of the kite.

"When the electricity of the kite is very ſtrong, I fix a chain, communicating with the ground, at about ſix inches diſtance from the ſtring; which may carry off its electricity, in caſe that this ſhould increaſe ſo much as to put the by-ſtanders in danger.

"Beſides the above-deſcribed apparatus, I have occaſionally uſed ſome other inſtruments, which I have often varied, according as ſome particular experiments required; but, as they are of no great conſequence, I ſhall omit to deſcribe them. It is only neceſſary, to give an idea of the ſtandard of my quadrant electrometer; which may, very probably, ſhew the ſame intenſity of electricity under a number of degrees different from the other inſtruments of the ſame kind. When the kite is flying, and the apparatus is diſpoſed as in fig. 128. I bring, under the extremity E of the prime conductor, a little bran, held upon a tin plate, and obſerve, that when the index of the electrometer is at ten degrees, the prime conductor begins to attract the bran at the diſtance of about three-fifths of an inch: when the index is at twenty degrees, the prime conductor attracts the bran at the diſtance of about one inch and a quarter; when the index is at thirty degrees, the bran begins to be attracted at the diſtance of two inches and one-fifth. Theſe diſtances vary, as the weather changes its degree of dryneſs; but in froſty weather I obſerve them conſtantly as above."

494 Inſtance of great danger.

Mr Cavallo has given copious extracts from a journal which he kept of his experiments with the kite; from theſe we ſhall give his account of one experiment, which is peculiarly intereſting from the danger to which the experimenters appear to have been expoſed.

"October the 18th. After having rained a great deal in the morning, and night before, the weather became a little clear in the afternoon, the clouds appearing ſeparated, and pretty well defined. The wind was weſt, and rather ſtrong, and the atmoſphere in a temperate degree of heat. In theſe circumſtances, at three P. M. I raiſed my electrical kite with three hundred and ſixty feet of ſtring. After that the end of the ſtring had been inſulated, and a leather-ball, covered with tin-foil, had been hung to it, I tried the power and quality of the electricity, which appeared to be poſitive, and pretty ſtrong. In a ſhort time a ſmall cloud paſſing over, the electricity increaſed a little; but the cloud being gone, it decreaſed again to its former degree. The ſtring of the kite was now faſtened by the ſilk lace to a poſt in the yard of the houſe wherein I lived, which was ſituated near Iſlington, and I was repeatedly charging two coated phials, and giving ſhocks with them:—while I was ſo doing, the electricity, which was ſtill poſitive, began to decreaſe, and in two or three minutes time it became ſo weak, that it could be hardly perceived with a very ſenſible cork-ball electrometer. Obſerving at the ſame time that a large and black cloud was approaching the zenith (which, no doubt, cauſed the decreaſe of the electricity) indicating imminent rain, I introduced the end of the ſtring through a window, in a firſt-floor room, wherein I faſtened it by the ſilk lace to an old chair. The quadrant electrometer was ſet upon the ſame window, and was, by means of a wire, connected with the ſtring of the kite. Being now three quarters of an hour after three o'clock, the electricity was abſolutely unperceivable; however, in about three minutes time, it became again perceiveable, but now upon trial was found to be negative; it is therefore plain, that its ſtopping was nothing more than a change from poſitive to negative, which was evidently occaſioned by the approach of the cloud, part of which by this time had reached the zenith of the kite, and the rain alſo had begun to fall in large drops.—The cloud came farther on;—the rain increaſed, and the electricity keeping pace with it, the electrometer ſoon arrived to 15°. Seeing now, that the electricity was pretty ſtrong, I began again to charge the two coated phials, and to give ſhocks with them; but the phials had not been charged above three or four times, before I perceived that the index of the electrometer was arrived at 35°, and was keeping ſtill increaſing. The ſhocks now being very ſmart, I deſiſted from charging the phials any longer; and, conſidering the rapid advance of the electricity, thought to take off the inſulation of the ſtring, in caſe that if it ſhould increaſe farther, it might be ſilently conducted to the earth, without cauſing any bad accident, by being accumulated in the inſulated ſtring. To effect this, as I had no proper apparatus near me, I thought to remove the ſilk lace, and faſten the ſtring itſelf to the chair; accordingly I diſengaged the wire that connected the electrometer with the ſtring; laid hold of the ſtring; untied it from the ſilk lace, and faſtened it to the chair; but while I effected this, which took up leſs than half a minute of time, I received about a dozen, or fifteen, very ſtrong ſhocks, which I felt all along my arms, in my breaſt, and legs; ſhaking me in ſuch a manner, that I had hardly power enough to effect my purpoſe, and to warn the people in the room to keep their diſtance. As ſoon as I took my hands off the ſtring, the electricity (in conſequence of the chair being a bad conductor) began to ſnap between the ſtring and the ſhutter of the window, which was the neareſt body to it. The ſnappings, which were audible at a good diſtance out of the room, ſeemed firſt iſochronous with the ſhocks which I had received, but in about a minute's time, oftener; ſo that the people of the houſe compared their ſound to the rattling noiſe of a jack going when the fly is off. The cloud now was juſt over the kite; it was black, and well defined, of almoſt a circular form, its diameter appearing to be about 40°; the rain was copious, but not remarkably heavy. As the cloud was going off, the electrical ſnapping began to weaken, and in a ſhort time became unaudible. I went then near the ſtring, and finding the electricity weak, but ſtill negative, I inſulated it again, thinking to keep the kite up ſome time longer; but obſerving that another larger and denſer cloud was approaching apace towards the zenith, as I had then no proper apparatus at hand, to prevent every poſſible bad accident, I reſolved to pull the kite in; accordingly a gentleman, who was by me, began pulling it in, while I was winding up the ſtring. The cloud was now very nearly over the kite, and the gentleman, who was pulling in the ſtring, told me, that he had received one or two ſlight ſhocks in his arms, and that if he were to feel one more, he would certainly let the ſtring go; upon which I laid hold of the ſtring, and pulled the kite in as faſt as I could, without any farther obſervation; being then ten minutes after four o'clock.

" *N. B.* There was neither thunder or lightning perceived that day, nor indeed for ſome days before or afterwards *."

Cavallo's conclusions.

From his experiments with the kite, Mr Cavallo deduces the following concluſions.

1. The air appears to be electrified at all times; its electricity is conſtantly poſitive, and much ſtronger in froſty, than in warm weather; but it is by no means leſs in the night than in the day-time (*k*).

2. The preſence of the clouds generally leſſens the electricity of the kite; ſometimes it has no effect upon it; and it is very ſeldom that it increaſes it a little.

3. When it rains, the electricity of the kite is generally negative, and very ſeldom poſitive.

4. The aurora borealis ſeems not to affect the electricity of the kite.

5. The electrical ſpark taken from the ſtring of the kite, or from any inſulated conductor connected with it, eſpecially when it does not rain, is very ſeldom longer than a quarter of an inch; but it is exceedingly pungent. When the index of the electrometer is not higher than 20°, the perſon that takes the ſpark will feel the effect of it in his legs; it appearing more like the diſcharge of an electric jar, than the ſpark taken from the prime conductor of an electrical machine.

6. The

* *Cavallo's Electricity*, vol. ii. 495

(*k*) In all his experiments, it happened only once that the ſtring of the kite gave no ſigns of electricity; it was one afternoon, when the weather was warm, and the wind ſo weak, that the kite was raiſed with difficulty, and could hardly be kept up for a few minutes; in the evening, however, the wind, which in the daytime had been north-weſt, ſhifted to the north-eaſt, blowing a little ſtronger: he then raiſed the kite again, being half paſt ten o'clock, and obtained, us uſual, a pretty ſtrong poſitive electricity.

6. The electricity of the kite is in general ſtronger or weaker, according as the ſtring is longer or ſhorter; but it does not keep any exact proportion to it: the electricity, for inſtance, brought down by a ſtring of a hundred yards, may raiſe the index of the electrometer to 20°; when, with double that length of ſtring, the index of the electrometer will not go higher than 25°.

7. When the weather is damp, and the electricity is pretty ſtrong, the index of the electrometer, after taking a ſpark from the ſtring, or preſenting the knob of a coated phial to it, riſes ſurpriſingly quick to its uſual place; but in dry and warm weather, it riſes exceedingly ſlow.

496
Application of Bennet's electrometer to the kite.

Mr Bennet obſerved with his electrometer, that in very clear weather, when no clouds were viſible, on applying the inſtrument to the inſulated ſtring of kites without metal, their poſitive electricity cauſed the ſlips of gold-leaf to ſtrike the ſides of the glaſs; but when a kite was raiſed in cloudy weather, with a wire in the ſtring, and when it gave ſparks about a quarter of an inch long, the electricity was ſenſible by the electrometer, at the diſtance of about ten yards from the ſtring; but when placed at the diſtance of ſix feet, the gold-leaf continued to ſtrike the ſides of the electrometer for more than an hour together, with a velocity increaſing and decreaſing with the denſity or diſtance of the unequal clouds that paſſed over.

Sometimes the electricity of an approaching cloud has been ſenſible without a kite, though in a very unfavourable ſituation for it, being in a town ſurrounded with hills, and where buildings encompaſſed the wall on which the electrometer was placed. A thunder cloud paſſing, cauſed the gold-leaf to ſtrike the ſides of the glaſs very quick at each flaſh of lightning.

Mr Bennet relates the following inſtance of the danger ſometimes incurred in making experiments with the kite. Having on the 5th of July 1788, raiſed a kite with two hundred yards of ſtring, when it had been flying for about an hour, a dark cloud appeared at a great diſtance, and changed the electricity from poſitive to negative. The electric power increaſed till the cloud became nearly vertical, when ſome large drops of rain fell; and Mr Bennet attempting to ſecure the ſtring from wet, received ſuch a ſtrong ſhock in his arm, as deprived it for a few ſeconds of ſenſation. The exploſion was heard at the diſtance of forty yards, like the loud crack of a whip.

497
Curious phenomenon obſerved by Mr Baldwin.

The following curious phenomenon was obſerved by Mr Loammi Baldwin, while raiſing an electrical kite in July 1771, during the approach of a ſevere thunder-ſtorm. He obſerved himſelf to be ſurrounded by a rare medium of fire, which, as the cloud roſe nearer the zenith, and the kite roſe higher, continued to extend itſelf with ſome gentle faint flaſhes. Mr Baldwin felt no other effect than a general weakneſs in his joints and limbs, and a kind of liſtleſs feeling; all which, he obſerves, might poſſibly be the effect of ſurpriſe, though it was ſufficient to diſcourage him from perſiſting in any farther attempt at that time. He therefore drew in his kite, and retired to a ſhop till the ſtorm was over, and then went to his houſe, where he found his friends much more ſurpriſed than he had been himſelf; and who, after expreſſing their aſtoniſhment, informed him, that he appeared to them (during the time he was raiſing the kite, to be in the midſt of a large bright flame of fire, attended with flaſhings; and, that they expected every moment to ſee him fall a ſacrifice to the flame. The ſame was obſerved by ſome of his neighbours, who lived near the place where he ſtood *.

Fig. 129. repreſents a very ſimple inſtrument, contrived by Mr Cavallo for making experiments on atmoſpherical electricity, and which, on ſeveral accounts, ſeems to be the moſt convenient for that purpoſe.

498
Cavallo's atmoſpherical electrometer.

AB is a common jointed fiſhing-rod, without the laſt or ſmalleſt joint. From the extremity of this rod proceeds a ſlender glaſs tube C, covered with ſealing-wax, and having a cork D, at its end, from which a pith-ball electrometer is ſuſpended. HGI is a piece of twine faſtened to the other extremity of the rod, and ſupported at G by a ſmall ſtring FG. At the end I of the twine a pin is faſtened, which, when puſhed into the cork D, renders the electrometer E uninſulated.

When he would obſerve the electricity of the atmoſphere with this inſtrument, he thruſt the pin I into the cork D, and holding the rod by its lower end A, projects it out from a window of the upper part of the houſe into the air, raiſing the end of the rod with the electrometer, ſo as to make an angle of about 50° or 60° with the horizon. In this ſituation he keeps the inſtrument for a few ſeconds, and then pulling the twine at H, diſengages the pin from the cork D; which operation cauſes the ſtring to drop in the dotted ſituation KL, and leaves the electrometer inſulated and electrified, with an electricity contrary to that of the atmoſphere.—This done, he draws the inſtrument into the room, and examines the quality of the electricity, without obſtruction either from wind or darkneſs.

With this inſtrument he made obſervations on the electricity of the atmoſphere, ſeveral times in a day for ſeveral months, and from them he deduces the following general obſervations, which ſeem to coincide with thoſe made with the electrical kites.

1. That there is in the atmoſphere, at all times, a quantity of electricity; for, whenever he uſed the above-deſcribed inſtrument, it always acquired ſome electricity.

2. That the electricity of the atmoſphere, or fogs, is always of the ſame kind, namely poſitive; for the electrometer is always negative, except when it is evidently influenced by heavy clouds near the zenith.

3. That in general, the ſtrongeſt electricity is obſervable in thick fogs, and alſo in froſty weather; and the weakeſt, when it is cloudy, warm, and very near raining: but it does not ſeem to be leſs by night than in the day time.

4. That in a more elevated place, the electricity is ſtronger than in a lower one; for, having tried the atmoſpherical electrometer, both in the ſtone and iron gallery on the cupola of St Paul's cathedral, Mr Cavallo found that the balls diverged much more in the latter than in the former leſs elevated place; hence it appears, that, if this rule takes place at any diſtance from the earth, the electricity in the upper regions of the atmoſphere muſt be exceedingly ſtrong.

499
His electrometer for rain.

Mr Cavallo has alſo contrived an inſtrument, which he calls his *electrometer for the rain*; this is merely an inſulated inſtrument to catch the rain, and, by means of a pith-ball electrometer, to ſhow the degree and quality of its electricity.

At fig. 130. is repreſented an inſtrument of this kind, which Mr Cavallo frequently uſed, and after

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* *Memoirs of the American Academy*, vol. i.

ſeveral obſervations, found to anſwer very well. ABCI is a ſtrong glaſs tube about two feet and a half long, having a tin funnel, DE, cemented to its extremity, which funnel defends part of the tube from the rain. The outſide ſurface of the tube from A to B is covered with ſealing-wax; ſo alſo is the part of it which is covered by the funnel. FD is a piece of cane, round which ſeveral braſs wires are twiſted in different directions, ſo as to catch the rain eaſily, and at the ſame time to make no reſiſtance to the wind. This piece of cane is fixed into the tube, and a ſlender wire proceeding from it goes through the bore of the tube, and communicates with the ſtrong wire AG, which is thruſt into a piece of cork faſtened to the end A of the tube. The end G of the wire AG is formed into a ring, from which is ſuſpended a more or leſs ſenſible pith-ball electrometer, as occaſion requires.

This inſtrument is faſtened to the ſide of the window-frame, where it is ſupported by ſtrong braſs hooks at CB, which part of the tube is covered with a ſilk lace, in order to adapt it better to the hooks. The part FC is out of the window, with the end F a little elevated above the horizon. The remaining part of the inſtrument comes through a hole in one of the lights of the ſaſh, within the room, and no more of it touches the ſide of the window than the part CB.

When it rains, eſpecially in paſſing ſhowers, this inſtrument, ſtanding in the ſituation above deſcribed, is frequently electrified; and, by the diverging of the electrometer, the quantity and quality of the electricity of the rain may be obſerved, without any danger of a miſtake. With this inſtrument, he obſerved, that the rain is generally, though not always electrified negatively, and ſometimes ſo ſtrongly, that he has been able to charge a ſmall coated phial at the wire AG.

This inſtrument ſhould be fixed in ſuch a manner, that it may be eaſily taken off from the window, and replaced again, as occaſion requires; for it will be neceſſary to clean it very often, particularly when a ſhower of rain is approaching.

500 Uſe of his multiplier.

Mr Cavallo has alſo ſhewn how the electricity of the atmoſphere may be obſerved by means of his multiplier, deſcribed in N°. 255.

In order to examine the electricity of the atmoſphere, he at firſt uſed to fix a long pointed wire into the ſocket of the plate A, and then expoſed it to the open air. But he has lately uſed a much better method of accompliſhing that object. He expoſes, out of the window, an inſulated ſtick of about five feet in length, and covered with tin-foil; and while he holds this apparatus by the extremity of its inſulating handle, he touches with the other hand, for about two or three ſeconds, the lower part of the ſtick. By this means, the ſtick being free from points, acquires an electricity contrary to that of the ſurrounding air. Mr Cavallo then brings it within the room, and communicates that electricity to the plate A of the multiplier, &c. But the electricity ſo acquired by the inſulated ſtick, is generally ſufficient to affect an electrometer without the uſe of the multiplier. To examine the electricity of the rain, ſnow, hail, &c. the ſame apparatus muſt be expoſed out of a window, but the ſtick muſt not be touched, for in this caſe, it acquires the ſame ſort of electricity as that of the rain, ſnow, &c. and not the contrary ſort, as when expoſed to the air.

501 Obſervations by Mr Read.

Mr Read, in his "Summary View of the Spontaneous Electricity of the Earth and Atmoſphere," obſerves, that the electricity of the atmoſphere, in moderate weather, was always found to be poſitive; in ſtorms and diſturbed ſtates of the air frequently negative; and ſuddenly and repeatedly changing from the one ſtate to the other. Warm ſmall rain, was found to be very ſlightly electric; large drops, ſtrongly; hail ſhowers, the moſt intenſely of all. In an eaſterly wind of long continuance, the electricity was ſo faint, as to require the niceſt of all known teſts for diſcovering its exiſtence. The vapour of water, as ſoon as it had attained the height of five or ſix inches of inſulation in the air, was found to be permanently and poſitively electrified; and the ſurface from which it evaporated, negatively. According to Mr Read, vapour has a greater capacity for electricity, or abſorbs and requires more of fluid, than water in its denſer ſtate; and, therefore, rarefaction muſt diminiſh, and condenſation increaſe, the ſenſible electric charge of the vapour. Hence, in ſerene weather, the atmoſphere is ſubject to a regular flux and reflux, or increaſe and diminution of electricity twice in every twenty-four hours, depending on the action of the ſun, and the conſequent evaporation and ſtate of the vapours. This diligent obſerver further remarks, that a limited portion of the earth's ſurface is often ſenſibly electrified; over it, there is always a proportionate ſtate of the contrary electricity in the atmoſphere; and when an electrified cloud is carried forward by wind, an equal and oppoſite electric charge keeps pace with it on the earth, till the two charges, becoming more augmented or approaching nearer to one another, or meeting with ſome conducting eminence, ruſh together, and produce an exploſion.

502 By Mr Sauſſure.

We ſhall conclude our account of experiments on atmoſpherical electricity, with thoſe made by M. Sauſſure in his excurſions among the Alps. The inſtrument employed by M. Sauſſure is a modification of Cavallo's atmoſpherical electrometer, and ſhall be deſcribed under the article ELECTROMETER.

The following are M. Sauſſure's obſervations on the electricity of the atmoſphere.

503 Obſervations on atmoſpheric electricity.

Aerial electricity varies according to the ſituation; it is generally ſtrongeſt in elevated and inſulated ſituations; not to be obſerved under trees, in ſtreets, in houſes, or any incloſed places; though it is ſometimes to be found pretty ſtrong on quays and bridges. It is alſo not ſo much the abſolute height of the places, as their ſituation: thus a projecting angle of a high hill will often exhibit a ſtronger electricity than the plain at the top of the hill, as there are fewer points in the former to deprive the air of its electricity.

The intenſity of the atmoſpheric electricity is varied by a great many circumſtances, ſome of which may be accounted for, others cannot. When the weather is not ſerene, it is impoſſible to aſſign any rule for their variation, as no regular correſpondence can then be perceived with the different hours of the day, nor with the various modifications of the air. The reaſon is evident; when contrary and variable winds reign at different heights, when clouds are rolling over clouds, theſe winds and clouds, which we cannot perceive by any exterior ſign, influence however the ſtrata of air in which we make our experiments, produce theſe changes of which we only ſee the reſult, without being

Atmoſpherical Electricity.

ing able to aſſign either the cauſe, or its relation. Thus, in ſtormy weather, we ſee the electricity ſtrong, then null, and in a moment after ariſe to its former force; one inſtant poſitive, the next negative; without being able to aſſign any reaſon for theſe changes. M. Sauſſure ſays, that he has ſeen theſe changes ſucceed with ſuch rapidity, that he had not time to note them down.

When rain falls without a ſtorm, theſe changes are not ſo ſudden; they are however very irregular, particularly with reſpect to the intenſity of force; the quality thereof is more conſtant. Rain, or ſnow, almoſt uniformly gives poſitive electricity.

In cloudy weather, without rain or ſtorms, the electricity follows generally the ſame laws as in ſerene weather.

Strong winds generally diminiſh its intenſity; they mix together the different ſtrata of the atmoſphere, and make them paſs ſucceſſively towards the ground, and thus diſtribute the electricity uniformly between the earth and the air; M. Sauſſure has obſerved a ſtrong electricity with a ſtrong north wind *(la biſe)*.

The ſtate of the air, in which the electricity is ſtrongeſt, is foggy weather: this is always accompanied with electricity, except when the fog is going to reſolve into rain.

The moſt intereſting obſervations, and thoſe which throw the greateſt light upon the various modifications of electricity in our atmoſphere, are thoſe that are made in ſerene weather. In winter, (during which moſt of M. Sauſſure's obſervations were made) and in ſerene weather, the electricity was generally weakeſt in an evening, when the dew had fallen, until the moment of the ſun's riſing; its intenſity afterwards augmented by degrees, ſometimes ſooner, and ſometimes later; but generally before noon, it attained a certain maximum, from whence it again declined, till the fall of the dew, when it would be ſometimes ſtronger than it had been during the whole day; after which, it would again gradually diminiſh during the whole night; but is never quite deſtroyed, if the weather is perfectly ſerene.

504 Periodical flux and reflux obſervable in the electricity of the atmoſphere.

Atmoſpherical electricity ſeems, therefore, like the ſea, to be ſubject to a flux and reflux, which cauſes it to increaſe and diminiſh twice in 24 hours. The moments of its greateſt force are ſome hours after the riſing and ſetting of the ſun; thoſe when it is weakeſt, precede the riſing and ſetting thereof. This will be further explained in the following pages.

M. Sauſſure has given an inſtance of this periodic flux in electricity, on the 22d of February, 1785; (one of the coldeſt days ever remembered at Geneva); the hygrometer and thermometer were ſuſpended in the open air, on a terrace expoſed to the ſouth-weſt; the electrometer, from its ſituation, indicated an electricity equal to what it would have ſhewn if it had been placed on an open plain. The height of the barometer is reduced to what it would have been if the mercury had been conſtantly at the temperature of 10 degrees of Reaumur's thermometer. The place of obſervation was elevated 60 feet above the level of the lake. The obſervations of the day preceding and following this great cold, are inſerted in the following table; becauſe it is pleaſing to have the obſervations which precede and follow any ſingular phenomena. There was a weak ſouth-weſt wind during the whole three days; and it is rather remarkable, that moſt of the great colds, which have been obſerved at Geneva, were preceded by, or at leaſt accompanied with, a little ſouth-weſt breeze.

TABLE.

	Barometer, feet in height.	Thermometer.	Hygrom.	Electrom.	
h. m.					
Feb. 21ſt, 9 15 M	26 6 7	— 8 3	89 3	2 0	Pale ſun, cloudy.
11 10 M	26 6 5	— 4 3	83 9	1 6	Bright ſun.
2 10 E	26 6 1	— 0 2	69 6	1 1	The ſame.
5 E	26 6 1	— 2 3	77 2	1 1	Setting ſun.
6 E	26 6 0	— 5 2	85	1 0	Cloudy in the S. W.
7 E	26 6 2	— 6 8	89	1 8	Perfectly clear.
8 E	26 6 3	— 10 0	95	2 0	Idem.
9 E	26 6 3	— 10 6	97 5	1 8	Idem.
10 E	26 6 1	— 9 9	95	1 2	Little cloud at horizon S.
11 E	26 6 0	— 12 3	99 1	1 5	Idem more to S. W.
12 E	26 5 15	— 12 5	Hoar froſt	1 2	Idem.
22d, 1 M	26 6 0	— 14 3	Idem	0 9	Idem.
2 M	26 6 8	— 14 5	Id.	1 2	Clouds increaſe and approach.
6 15 M	26 5 7	— 15 0	Id.	0 8	Clear.
7 30 M	26 5 4	— 14 7	Id.	1 2	Light fog.
8 10 M	26 5 2	— 14 2	Id.	1 1	Idem.
9 10 M	26 4 15	— 10 7	Id.	1 6	Idem.
10 10 M	26 4 13	— 8 2	Id.	2 2	Thicker fog.
11 10 M	26 4 3	— 4 8	Id.	1 8	Idem.
1 10 E	26 4 0	— 4 9	Id.	1 7	Idem.
2 20 E	26 3 14	+ 0 6	82	1 4	Weak fog, pale ſun.

h. m.	Barometer, feet in height.	Thermometer.	Hygrom.	Electrom.	
Feb. 22d, 3 30 E	26 3 13	— 0 9	81 9	1 1	Cloudy pale ſun.
5 E	26 3 13	— 4 3	89	1 2	Leſs cloudy.
6 E	26 3 14	— 4 4	91 2	2 2	More ſo.
7 E	26 3 14	— 6 1	94	1 7	Idem.
8 E	26 3 13	— 5 9	Id.	3 7	Cloudy foggy in S. W.
23d 0 45 M		— 4 1	Id.	1 0	Cloudy with more fog.
8 5 M	26 5 0	— 1 0	81 3	1 2	Idem.
10 7 M	26 5 5	— 0 0	76	0 8	Idem.
3 45 E	26 6 8	+ 0 5	76	Id.	Cloudy pale ſun.
5 E	26 6 14	— 0 3	75 3	1 0	Cloudy.
6 E	26 7 3	— 0 7	74	0 8	Idem.
7 E	26 7 9	— 1 7	79 7	2 2	Very clear.
8 E	26 7 14	— 3 7	87 3	1 7	Cloudy.
12 E	26 9 1	— 3 0	92	0 5	More ſo.

M for Morning, E for Evening.

From the firſt 18 obſervations of this table, when the ſky was quite ſerene, we ſee that the electricity was pretty ſtrong at nine in the morning; that from thence it gradually diminiſhed till towards ſix in the evening, which was its firſt minimum; after which it increaſed again till eight, its ſecond maximum; from whence it again gradually declined till ſix the next morning, which was the time of its ſecond minimum; after which, it again increaſed till ten in the morning, which was the firſt maximum of the following day: as this was cloudy, the electric periods were not ſo regular.

505 Electricity weaker in ſummer than in winter.

The electricity of ſerene weather is much weaker in ſummer than in winter, which renders it more difficult to obſerve theſe gradations in ſummer than in winter; beſides a variety of accidental cauſes, which at the ſame time render them more uncertain. In general, in ſummer, if the ground has been dry for ſome days, and the air is dry alſo, the electricity generally increaſes, from the riſing of the ſun till three or four in the afternoon, when it is ſtrongeſt: it then diminiſhes till the dew begins to fall, which again reanimates it; though after this it declines, and is almoſt extinguiſhed during the night.

But the ſerene days that ſucceed rainy weather in ſummer, generally exhibit the ſame diurnal periods or ſtates of electricity, as are to be obſerved in winter.

506 Electricity of the air in ſerene weather naturally poſitive.

The air is invariably poſitive in ſerene weather, both in winter and ſummer, day and night, in the ſun or in the dew. It would ſeem, therefore, that the electricity of the air is eſſentially poſitive, and that whenever it appears to be negative, in certain rains or in ſtorms, it probably ariſes from ſome clouds, which have been expoſed to the preſſure of the electric fluid contained in the upper part of the atmoſphere, or to more elevated clouds, that have diſcharged a part of their fluid upon the earth, or upon other clouds.

507 In order to find out the cauſe of theſe phenomena, Mr Sauſſure inſtituted a ſet of experiments on evaporation, avoiding the uſe of Volta's condenſer.

To produce a ſtrong evaporation, he threw a maſs of red hot iron into a ſmall quantity of water, which was contained in a coffee-pot, with a large mouth, and ſuſpended by ſilk ſtrings; by this he obtained a ſtrong poſitive electricity, though, according to M. Volta's ſyſtem, it ought to have been negative. The experiment was repeated ſeveral times, varying ſome of the circumſtances, but the reſult was always the ſame.

As it was not eaſy to think ſo able a philoſopher as M. Volta was deceived, it was neceſſary to try the experiment in a manner more analogous to that of M. Volta. A ſmall chafing-diſh was therefore inſulated by ſilk cords, and the coffee-pot, with a ſmall quantity of water, placed on it; one electrometer was connected with the coffee-pot, and another with the chafing-diſh; the fire was raiſed by a pair of bellows: when the water had boiled ſtrongly for a few minutes, both electrometers exhibited ſigns of electricity, which, on examination, was found to be negative; proving the truth of M. Volta's experiment. The evaporation produced by the efferveſcence of iron in the ſulphuric acid, and by that of chalk in the ſame acid, gave alſo negative electricity.

It was now neceſſary to inquire, why the vapour, excited by the heated iron, produced poſitive electricity; while that from boiling water, in any other way, produced a negative electricity.

M. Sauſſure ſuſpected, that the intenſity of heat to which the water is expoſed, by the contact of a body in a ſtate of incandeſcence, was the cauſe of the electricity produced by its evaporation; and that a combination was then formed, by which a new quantity of the electric fluid was produced. This conjecture may at firſt ſight ſeem improbable; but the quantity of electricity produced by this experiment will aſtoniſh thoſe that repeat it; and this quantity is more ſurpriſing, becauſe, if it is true, according to the ſyſtem of M. Volta, that the vapours abſorb, while they are forming, a quantity of the electric fluid, there muſt, therefore, be enough developed in this experiment, for the formation of the great quantity of vapours produced by the heated iron, and afterwards a ſufficient quantity to electrify ſtrongly the apparatus, and all theſe vapours.

This experiment ſhews clearly the cauſe of that prodigious quantity of electricity, which is unfolded in the eruption of volcanoes; as it is probable, that the water in theſe, from many circumſtances, acquires a much greater degree of heat than is given to it in our experiments.

508 Explanation of the great quantity of electricity apparent in the eruptions of volcanoes.

To verify this conjecture, that it was in ſome meaſure the combuſtion of the water, or the iron, that produced the poſitive electricity, it was proper to try whether, by a regular moderation of the heat of the iron, poſitive electricity would always be obtained. This was eſſayed in the following manner: A large iron crucible, five inches high, four in diameter, and ſix lines thick, was heated red hot; then inſulated; after which, ſmall quantities of water were thrown into it, each projection of the water cooling more and more the crucible; thus deſcending by degrees till there was only ſufficient heat to boil the water; carefully obſerving, and then deſtroying the electricity produced at each projection. The electricity was always poſitive or null; at the firſt projections it was very ſtrong; it gradually diminiſhed to the twelfth, when it was ſcarce ſenſible, though always with a tendency to be poſitive.

On repeating this experiment, and varying it in different ways, a remarkable circumſtance was obſerved: When a ſmall quantity of water was thrown into the crucible, the moment it was taken from the fire, while it was of a pale red, approaching what is called the white heat, no electricity was obtained.

This fact ſeemed to have ſome connection with another mentioned by Muſchenbroek, that water evaporates more ſlowly on a metal, or any other incandeſcent body, than on the ſame body, heated only a ſmall degree above boiling water. To examine this relation, and to find whether there was any between the periods of evaporation, and the production of electricity, M. Sauſſure made a great number of experiments, which are moſt accurately deſcribed in his excellent work; but as the detail would be much too long to be introduced in this article, we muſt content ourſelves with preſenting the reader with the heads thereof, and a deſcription of the apparatus.

509 Experiments on evaporation.

The apparatus conſiſted of a pot of clay, well baked or annealed, fifteen lines thick, and four inches in diameter; this was inſulated by a dry glaſs goblet; upon this pot was placed the crucible, or any other heated ſubſtance, on which the water was to be thrown, in order to be reduced into vapours; the crucible was contiguous to a wire connected with an electrometer; a meaſure, containing 54 grains weight of diſtilled water, was thrown upon the heated crucible; the time employed in the evaporation thereof was obſerved by a ſecond watch; the electricity produced by this evaporation was noted. When this meaſure of water was reduced into vapour, the electricity of the apparatus was deſtroyed, and a freſh meaſure of water was thrown into the crucible; proceeding in the ſame manner till the crucible was almoſt cold.

The firſt experiment was with an iron crucible, from which it was found, that Muſchenbroek was not right, in ſaying that the evaporation was ſloweſt when the iron was hotteſt; for at the inſtant it was taken from the fire it required 19 ſeconds to evaporate the water, and took more time till the third projection, when it took 35 ſeconds, though from that period it employed leſs time, or in other words, the evaporation accelerated in proportion as the iron cooled.

With reſpect to the electricity, it was at firſt 0, then poſitive, afterwards negative, then 0, and afterwards poſitive to the end of the experiment. The vapour was not viſible till the 7th projection.

In the ſecond experiment with the ſame crucible, though every endeavour was made uſe of to render them as ſimilar as poſſible, the electricity was conſtantly poſitive.

The third experiment was with a copper crucible; here alſo the electricity was poſitive, and the longeſt time employed in evaporation was not the inſtant of the greateſt heat. It was very curious to ſee the water endeavouring to gather itſelf into a globule, like mercury on glaſs; to be ſometimes immoveable, and then to turn on itſelf horizontally, with great rapidity; ſometimes throwing from ſome of its points a little jet, accompanied with a hiſſing noiſe.

The fourth experiment was with the ſame crucible; the electricity was at firſt negative, then conſtantly poſitive.

The fifth was with a crucible of pure ſilver; a conſiderable time was employed here in evaporating the ſame quantity of water; even in the inſtant of the greateſt heat it took five minutes, ſix ſeconds; the electricity was weak, three times no electricity was perceived, five times negative electricity was diſcovered.

In a ſixth experiment with the ſame crucible, a poſitive electricity was obtained, at the ſecond projection; after which none of any kind was perceived.

The ſeventh with the ſame, gave at firſt ſtrong negative electricity, the ſecond and third projection gave a weak poſitive electricity.

The eighth was made with a porcelain cup; here the evaporation was ſlower at the ſecond, than the firſt projection; but from this it took longer time till it was cold, contrary to what happened with the metals; the electricity was always negative.

The ninth and tenth experiments, with the ſame cup, produced ſimilar effects.

The eleventh experiment was with ſpirits of wine in a ſilver crucible; here there was no electricity produced at the two firſt projections, and what was afterwards obtained was negative.

Twelfth experiment with ether; here the electricity was alſo negative. Theſe two inflammable fluids, in evaporating, followed the ſame laws as water, being diſſipated at firſt moſt rapidly in the greateſt heat, afterwards taking a longer and longer time before they were evaporated, to a certain period, then employing leſs time, or evaporating quicker, till the crucible was nearly cold.

Now as china and ſilver always produced negative electricity, while iron and copper have generally given poſitive electricity, we may conclude, that electricity is poſitive with thoſe bodies that are capable of decompoſing water, or of being decompoſed themſelves by their contact with the water; and negative with thoſe which are not at all decompoſed or altered.

If in the foregoing experiment, thoſe ſubſtances which were ſuſceptible of oxidation had conſtantly given a poſitive electricity, and thoſe which do not oxidate had always given the negative; every thing would have been explained by theſe principles, and they would thence have acquired a greater degree of probability. But the phenomena have not always followed this law.

We have ſeen iron and copper ſometimes give a negative electricity, and ſilver the poſitive. The firſt caſe is not difficult to account for; it is well known with what facility iron and copper are oxidated in a briſk fire; they become covered with a ſcaly cruſt, which is not ſuſceptible of any further alteration with the ſame heat. If the bottom of the crucible acquires this cruſty coating, the drop of water placed thereon will be no longer in contact with an oxidable ſubſtance; there will be no further decompoſition, no generation of the electric fluid: the vapours, however, which are ſtill formed, will abſorb a part of the fluid naturally contained in the apparatus, and this will therefore be electrified negatively. If ſome of the ſcales ſhould be ſo far detached, that the water may gain ſome points of contact, the quantity thus generated may compenſate for what is abſorbed by the vapours, and thus the electricity will be null. If more are detached, it will ſuper-abound and be poſitive. From the ſame reaſons, a large maſs of water, by attacking the iron in a greater number of points, always gives poſitive electricity; and hence, alſo, a ſtrong poſitive electricity is obtained, by throwing a piece of red-hot iron into a maſs of water.

It is not ſo eaſy to explain why ſilver gives ſometimes a poſitive electricity, but by ſuppoſing it to have been mixed with ſome ſubſtances capable of oxidation; and this the more, as the white porcelain always gave negative electricity. This ſuppoſition was verified by ſome ſubſequent experiments, in which the ſame ſilver, when purified, always gave a negative electricity.

M. Sauſſure owns himſelf incapable of explaining why heated charcoal always gives negative electricity; unleſs it can be attributed to the promptitude with which ſo rare a ſubſtance loſes its heat, by the contact of water.

One fact aſtoniſhed him, namely, that by combuſtion properly ſo called, although it is an evaporation, nay, the higheſt degree of evaporation, he never obtained any ſigns of electricity; though he tried to obtain it in a variety of ways. Probably, the current produced by the flame, diſperſes and diſſipates the electricity as ſoon as it is formed. The caſe, however, muſt not be looked upon as general, becauſe M. Volta obtained ſigns of electricity from bodies in combuſtion, by means of his condenſer.

Another ſingular fact was, his not being able to obtain electricity without ebullition, though he endeavoured to compenſate by the quantity of ſurface for the quantity of vapours that were elevated by boiling water; and indeed, the ſame quantity of water, if extended over too large a ſurface, will not give any electricity.

We ſhall reſume this ſubject immediately, but muſt firſt conclude our obſervations on the phenomena of atmoſpherical electricity.

The following axioms with reſpect to atmoſpherical electricity, deduced by M. Cotte after a long courſe of obſervations, merit attention.

510 Cotte's axioms.

1. Electricity manifeſts itſelf oftener without ſtorms than with them.

2. It is produced more frequently by dry than by rainy clouds.

3. It is more frequently poſitive than negative, eſpecially when occaſioned by ſtationary clouds.

4. The atmoſphere exhibits ſigns of electricity at all times by night or day.

In our endeavours to explain the production of natural electricity, we have nothing more to do, than to diſcover the various circumſtances of the atmoſphere, in which moiſture is abſorbed or precipitated.

511 Cauſes of atmoſpherical electricity.

512 Abſorption and precipitation of aqueous particles.

It is neceſſary to recollect the proof furniſhed by numerous experiments, that when any portion of the atmoſphere is in a ſtate to take up an additional quantity of moiſture, it is in a ſtate at the ſame time to take up more electric fluid; and *vice verſa*, when it is parting with its water, it is at the ſame time parting with its electric fluid. But in theſe caſes, neither the ſuperabundance nor the deficiency can produce a charge, unleſs there be ſome other part of the air contemporaneouſly in an oppoſite ſtate, or in a diſpoſition either to receive or give. It is, however, ſcarcely poſſible that this ſhould not always happen; for our atmoſphere is, throughout its vaſt dimenſions, each moment agitated by millions of co-inſtantaneous changes, and for our purpoſe, it is of no conſequence where the required change takes place. Were it New Holland, or at the Antipodes, a connection would be inſtantly formed between the remote but oppoſite ſituations, by the conducting power of the earth.

513 Violence of ſtorms correſpondent to theſe.

It is a neceſſary concluſion from what we have juſt ſaid, that if the abſorption of moiſture by air, or the copious evaporation of it from the earth, be attended with a new accumulation of the fluid; then *where* this cauſe operates moſt powerfully, *there* its correſpondent effect will be moſt ſenſible. We conſequently find, that the moſt tremendous electrical phenomena belong to the countries within the tropics, or to that portion of our atmoſphere which is loaded with moiſture by the moſt powerful influence of the ſun's rays. In like manner, within the limits of our own and other ſimilar climates, electrical phenomena are greateſt, both in force and frequency, during the hotteſt months of the year, or during the ſeaſon in which our atmoſphere is moſt copiouſly and rapidly charged, by abſorbing the humidity of the ground.

514 Electrical appearances of volcanoes.

In the neighbourhood of Ætna and Veſuvius, during the period of their volcanic fury, ſurfaces, covering the dimenſions of ſeveral ſquare leagues, are ſometimes ſcorched with red-hot lava, and every atom of their moiſture is rapidly diſſipated. At the ſame time the ſurrounding air is heated to a vaſt extent, and in this ſtate ſwallows up an immenſe quantity of aqueous vapour; but contemporaneouſly with the operation of theſe powers, according to the reports of all natural hiſtorians, an immenſe quantity of the electric fluid is accumulated and diſcharged.

515 Storms peculiar to the torrid zone.

Again, a dry wind paſſing over a moiſt ſoil is another modification of the cauſe we are applying; it produces a copious and rapid ſolution of the aqueous particles, and its conſequent alteration of attractive force. Let us for inſtance, ſuppoſe a wind, which had paſſed over the deſerts of Arabia, or that had been torrefied in its paſſage over a large extent of burning ſands, to come in contact with a ſimilar extent of marſhy ſoil, or of any ſurface well drenched with water, a moſt abundant evaporation would neceſſarily take place, and with it an immenſe accumulation of the electric fluid. But ſubſequently, in caſe any power operated, which would take away the aqueous particles thus diſſolved, and of courſe alter the degree of attractive force by which the collected electric fluid is ſuſpended, we ſhould find that the moſt dreadful thunder-ſtorms would take place. This is really the caſe; for there is ſcarcely a region in the vaſt circle ſurrounding the immeaſurable ſands of Africa, which is not remarkable for ſtorms and tempeſts.

On the ſide of Abyſſinia, when the warm winds that have paſſed over the neighbouring deſerts are condenſed on its mountains, thoſe deluges are collected, which form the inundations of the Nile.

On the coaſt of Guinea, the *harmattan*, which is a current of air ſo dry, as to wither and pulverize, by a complete abſorption of all its juices, every ſubſtance that occurs in its paſſage, is no ſooner mixed with that body of air which is cooled by the ocean, than it forms moſt terrific hurricanes of wind and lightning that are deſcribed by navigators. Along the Syrian regions, we learn from ſacred authority, that the ſtorms gather with ſuch rapidity, that a cloud, which this inſtant might be covered with the hand, is within the interval of a few minutes, charged with water adequate to the inundation of a whole country.

The thunder that attended theſe impetuous ſtorms, provoked the ſublimeſt expreſſions of their poets. Indeed, whenever their minds attempt the deſcription of celeſtial greatneſs, or the ſudden and overwhelming approach of divine power in its triumph, or in its fury, they have recourſe for imagery to thoſe thunder-clouds, which they juſtly repreſented as extinguiſhing the light of the ſun, and as involving the world in a few inſtants in the darkneſs of midnight.

516
Application of the various caſes of precipitation.

Having ſpecified the two moſt general cauſes of evaporation on the ſurface of this earth, let us now attend to the poſſible changes of the atmoſphere, when by the operation of either, or both, it is charged with the electric fluid. All theſe changes are but different degrees of the ſame effect, viz. the condenſation of moiſture, and this condenſation is in every caſe produced by an alteration of temperature, which may proceed,

517
Mixture of a colder with a warmer air.

1. From a mixture, or even the contact, of a colder with a warmer air. When the ſmalleſt clouds are formed by ſuch a mixture, an electrical charge takes place, ſo that one part of the cloud has more, and the other leſs, than its natural ſhare. Fogs, dews, and the ſlighteſt change of clear for hazy weather, commonly ariſe from a warmer atmoſphere coming in contact with one of a lower temperature; but even theſe trifling degrees of condenſation are always followed by ſigns of electricity *.

In this country, from its inſular ſituation, which expoſes it to the perpetual influence of varying winds, the air changes its appearances often many times in one day. But there is no degree of thick cloudineſs or perfect clearneſs, of ſcattered clouds ſucceeding embodied maſſes of clouds, of ſmall rain increaſing to heavy, or *vice verſa*, that is not attended with changes in the expreſſions of the elevated conductor, which never fails to vary with all the atmoſpheric condenſations and rarefactions that take place.

It is, however, obvious that the effect muſt be in proportion to the quantity and rapidity of the condenſation. When, therefore, any body of air has been for a long time ſuſpended over a ſurface of ground previouſly drenched with ſhowers, and at the ſame time expoſed to the violence of the ſun's rays, a change in the direction of the wind, or ſuch a change in the weight of the air as mixes the upper with the lower regions of the air, is almoſt always attended with a thunder-ſtorm.

In tropical climates, for months together, ſcarcely a day paſſes, in which the calm atmoſphere is not loaded by ſucceſſive additions of moiſture, till at laſt, it becomes the reſervoir of vaſt rivers and lakes, and of all the moiſture that is ſpread over whole continents. But when this drought has reached its criſis, the ſun croſſes the line, the wind takes a new direction, a colder air mixes with that which is thus charged with vapours, and the condenſation becomes ſo copious, as to inundate all the ſubjacent country; but the deluge is not more deſtructive than its attendant ſtorm; for, according to the reports of ſpectators, our imaginations, confined to the proceedings of nature in this frozen region, have no images from which any ſuch compariſon can be made, as will communicate the leaſt idea of the thunder attending a tropical hurricane.

The cauſe which we are now applying to the explanation of theſe natural appearances, will furniſh us with an eaſy ſolution of a difficulty which has oppreſſed ſeveral theories of electricity, namely, that rapid generation and increaſe of the electric fluid which takes place in ſome thunder-ſtorms. Even in this country, the ſucceſſion of flaſhes is ſometimes ſo quick, that one hundred and twenty have been known to follow each other in a minute. In Aſia, this celerity of accumulation and diſcharge was ſo great, that Homer uſes it as part of a ſimile, by which he paints the quick repetition of Agamemnon's ſighs and pantings in an hour of diſtreſs.

It may be aſked, if each diſtinct cloud is loaded with a diſtinct charge, and if each flaſh is a ſeparate diſcharge of ſuch a cloud, what is there, in our knowledge of natural powers, that will account for an innumerable repetition of theſe accumulations and diſcharges within a very ſhort ſpace of time, more eſpecially when each of them is connected in our minds with the neceſſity of a diſtinct part of that time for its proceſs? In other words, do we know of any cauſe that is adequate to the filling and emptying of the ſame portion of air every inſtant, for hours together?

On a hot ſummer's day it not unfrequently happens, that a fine blue ſky will, within five ſeconds, be changed into one maſs of clouds. If the cauſe which produced ſo great an effect, were ſuppoſed to be doubled in its power of condenſation, the degree of electricity ſhown by the elevated conductor would be rather more than doubled, and its ſigns would be much ſtronger than in a common ſtorm; we may hence conclude, that the whole maſs which might be thus formed in five ſeconds, would be loaded ſo as to have every part of it at the diſcharging height; but the maſs might conſiſt of hundreds of diſtinct clouds all in the ſame ſtate, and conſequently adequate to the production of ſeveral hundred flaſhes within a minute.

The collapſe of aqueous particles, which would neceſſarily follow ſuch a rapid ſucceſſion of diſcharges as have been now proved to be poſſible, would produce a partial vacuum of great extent, and on all ſides the heavier air would ruſh into it, and the upper and colder regions would preſs downwards, and by their condenſing temperatures, would renovate all the accumulations and diſcharges which have been already deſcribed: a ſecond collapſe would follow a ſecond ſeries of thunder-ſtrokes,

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* Vide *Read on ſpontaneous Electricity.*

thunder-ſtrokes, and a partial vacuum additional to the former; a freſh portion of warm air would again ruſh in from all quarters, and a freſh mixture of cold air from the upper regions. It is ſcarcely neceſſary to ſhow that this repetition of condenſations may continue for hours, or till the air, which ruſhes in laterally, becomes of ſuch a temperature, that its mixture with the colder air will not produce the condenſations adequate to the collection of that quantity of electric fluid which is neceſſary for a diſcharge.

From this explanation, it is obvious that a central point muſt exiſt, at which the violence of every ſtorm begins, and from which it is ſpread in all directions. A hurricane in the Weſt Indies, though ruinous to many, is generally the diſtinguiſhing calamity of one iſland, at which alone the wind is deſcribed as blowing from every point of the compaſs; while in every other iſland, it is repreſented as bearing down deciſively from one quarter.

518 Heated air coming in contact with the cold earth.

2. The precipitation of aqueous particles when ſuſpended by heat in air, is frequently the conſequence of the loaded atmoſphere's coming in contact with portions of the earth that are colder than itſelf. Such, particularly, are the ſummits of mountains, whoſe effect is great in proportion to the degree of their cold and the extent of their ſurface. It is, however, certain that condenſations, when thus produced, are invariably attended by thunder-ſtorms.

The uproar, and the ſplendour of the innumerable lightnings, which dart through all the entangled circuits of an abyſs of thunder-clouds, are the immutable attributes of grandeur which belong to the Cordilleras; for they dam up, as it were, an immenſe flow of air, which is almoſt ſaturated with moiſture by paſſing over ſeveral thouſand leagues of land, expoſed to the fury of a tropical ſun.

In ſummer, the north-weſterly winds that paſs over France, are always condenſed by the Alps; and in the night, during ſuch a ſtate of the atmoſphere, to all thoſe who live along the Saone and the upper part of the Rhone, theſe mountains are always brightened by electrical flaſhes and corruſcations.

All ridges or chains of very high grounds, eſpecially thoſe which terminate extenſive plains lying in the direction of their moſt common winds, are perpetually beclouded; and with a good conductor, fixed on their ſummit, we ſhould find that the ſigns of electricity were as conſtant as the condenſations by which they are enveloped. But in proportion to the coldneſs, ſo is the ſubſequent change of temperature on the eminences diminiſhed, and the electrical effect dependant on that change. It hence happens, that there are countries in the northern parts of Europe, the gloom of whoſe miſts is never diſperſed by a thunder-ſtorm, excepting in the hotteſt ſeaſon of ſnmmer.

519 Sudden interruption of the ſun's influence.

3. When the ſun, by directing its rays with force and abundance upon the earth for any length of time, has produced a conſiderable evaporation, the mere interruption of its influence will be attended with a diſcharge of the electric fluid; for the great ſource of change in our atmoſphere is the ready influence of its upper regions, which are cold, on its lower regions when warmed; and any cauſe which mixes theſe together, muſt bring on a condenſation of aqueous vapour. This mixture, however, takes place on the mere approach of night, as is evident from the change of temperature expreſſed by the thermometer, and the uſual fall of the dews; we conſequently find, that as night comes on, the ſigns of electricity always increaſe. When the weather is tolerably ſettled, or ſuch that no other cauſe is active than that proceeding from the change of day for night, or night for day; then the ſigns of electricity gradually decreaſe from twelve o'clock at night till ſix in the morning; from this hour till nine, they gradually increaſe, when they become exceedingly weak, and continue ſo till four in the afternoon: the increaſe at this time recommences, and is very deciſive in its appearance till about two hours after ſunſet, when it becomes ſtationary, and remains in this ſtate, or decreaſing, ſo as ſcarcely to be ſenſible, till the morning *.

The cauſe, whoſe operation we have now inveſtigated in the production of its moſt feeble effects, may be eaſily applied to many other cauſes, in which ſimilar, but greater powers are diſplayed by nature. Let us ſuppoſe, that on a wide ſurface of ground, previouſly warmed by the ſun, copious ſhowers of rain had fallen, followed by a return of the ſun's influence; in this caſe, the evaporation is neceſſarily very rapid, and the ſigns of electricity expreſſed by an elevated conductor are very ſtrong.

When a copious production of electric fluid has attended a copious evaporation continued for ſeveral ſucceſſive hours, a thunder-ſtorm, or ſome ſtriking electrical appearance will come on with the approach of night; for unleſs the barometer ſhould ſuddenly riſe, the condenſation attending the evening's cold muſt be very conſiderable, and its uſual conſequences proportionally great. Such a day as we have juſt deſcribed, is uſually followed by a violent thunder-ſtorm. Indeed, there is ſcarcely an inſtance in which a moiſt ground, operated on for ſome hours by a clear ſun, provided the wind continues to blow from the ſouth-weſt or weſt, is not attended the following night by the appearance of falling ſtars, flaſhes of lightning, or the *Aurora Borealis*.

520 Effect of winds on the electricity of the atmoſphere.

We have alluded to the connection of winds with the phenomena of atmoſpherical electricity. The influence of winds muſt depend on various circumſtances; in ſome caſes, they will tend to diminiſh electrical appearances, and in others, they may altogether deſtroy them. The current of air which proceeds from a mixture of two winds of different temperatures, is the effect of a condenſation of vapour, that may be ſucceeded by the moſt violent ſtorms. But if there ſhould be two neighbouring regions, in one of which, the rays of the ſun ſhould co-operate with the moiſture of the ground, in producing electricity, while in the other there ſhould prevail a condenſation favourable to the diſcharge of the electric fluid; a current of air would be produced that would act like a communicating rod between two oppoſite electrified ſurfaces, would exchange the ſituations of the charged bodies, and would conſequently cauſe the new ſituation to counteract the effects produced in the laſt. This effect would be more ſenſible in proportion as the exchange has been more rapid, and accordingly we find, that during high winds, the electricity of the atmoſphere is very ſmall *.

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* Vide *Read on ſpontaneous Electricity*.

* *Morgan's Lectures*, vol. ii.

CHAP. III. *Of the Aurora Borealis.*

Most of the luminous appearances in the atmoſphere have of late been attributed to electricity. Of theſe we ſhall at preſent only conſider the *Aurora Borealis*, or *Northern Lights*, reſerving the account of other meteors for the article Meteorology.

521 Phenomena of the aurora borealis. The aurora borealis is uſually of a reddiſh colour, inclining to yellow, ſending out frequent coruſcations of pale light, which ſeem to riſe from the horizon in a pyramidal undulating form, ſhooting with great velocity towards the zenith. This light ſometimes appears remarkably red, as it happened December 5. 1737.

The aurora borealis appears frequently in the form of an arch; chiefly in ſpring and autumn, after a dry year. This arch is partly bright, partly dark, but generally tranſparent; and no change is found to be produced by it on the rays of light which paſs through it. It ſometimes produces a rainbow.

This kind of meteor, which becomes more uncommon as we approach towards the equator, is almoſt conſtant during the long winter of the polar regions, and appears there with the greateſt luſtre.

In the Shetland iſles, the *merry dancers*, as the northern lights are there called, are the conſtant attendants of clear evenings, and afford great relief amid the gloom of the long winter nights. They commonly appear at twilight, near the horizon, of a dim colour, approaching to yellow; ſometimes continuing in that ſtate for ſeveral hours, without any perceptible motion; and afterwards breaking out into ſtreams of ſtronger light, ſpreading into columns, and changing ſlowly into numberleſs different ſhapes, and varying in colour from all the tints of yellow, to the moſt obſcure ruſſet brown. They often cover the whole hemiſphere, then exhibiting the moſt brilliant appearance. Their motions at this time are exceedingly quick, and they aſtoniſh the ſpectator with the rapid change of their form. They break out in places where none were ſeen before, ſkim briſkly along the heavens, are ſuddenly extinguiſhed, and are ſucceeded by a uniform duſky tract. This again is brilliantly illuminated in the ſame manner, and as ſuddenly becomes a dark ſpace. In ſome nights, they aſſume the appearance of large columns, on one ſide of the deepeſt yellow, and on the other gradually changing, till it becomes undiſtinguiſhable from the ſky. They have generally a ſtrong tremulous motion from one end to the other, continuing till the whole vaniſhes. As for us, who ſee only the extremities of theſe phenomena, we can have but a faint idea of their ſplendour and motions. They differ in colour according to the ſtate of the atmoſphere, and ſometimes aſſuming the colour of blood, they make a dreadful appearance. The ruſtic ſages who obſerve them become prophetic, and terrify the ſpectators with alarm of war, peſtilence, and famine; nor indeed were theſe ſuperſtitious preſages peculiar to the northern iſlands: appearances of a ſimilar nature are of an ancient date; and they were diſtinguiſhed by the appellatious of *phaſmata*, *trabes*, and *bolides*, according to their forms and colours. In old times they were either more rare or leſs frequently noticed; but when they occurred, they were ſuppoſed to portend great events, and the timid imagination formed of them aërial conflicts.

In the northern latitudes of Sweden and Lapland, the *aurora borealis* is not only an object of pleaſing curioſity from the ſingular beauty of its appearance, but is extremely uſeful in affording to travellers, by its almoſt conſtant effulgence, a very brilliant light. In Hudſon's bay, it is ſaid to poſſeſs a variegated ſplendour, equalling that of the full moon. "In the north-eaſtern parts of Siberia," ſays Gmelin, "theſe northern lights are obſerved to begin with ſingle bright pillars riſing in the north, and almoſt at the ſame time in the north-eaſt, which gradually increaſing, comprehend a large ſpace of the heavens, ruſh about from place to place with incredible velocity, and finally almoſt cover the whole ſky up to the zenith, and produce an appearance as if a vaſt tent was ſpread in the heavens, glittering with gold, rubies, and ſapphire. A more beautiful ſpectacle cannot be painted; but whoever ſhould ſee ſuch a northern light for the firſt time, could not behold it without terror. For however fine the illumination may be, it is attended, as I have learned, with ſuch a hiſſing, cracking, and ruſhing noiſe through the air, as if the largeſt fireworks were playing off. To deſcribe what they then hear, they make uſe of the expreſſion *ſpolochi chodjat*, i. e. "the raging hoſt is paſſing." The hunters who purſue the white and blue foxes in the confines of the Icy ſea, are often overtaken with theſe northern lights. Their dogs are then ſo frightened, that they will not move, but lie obſtinately on the ground till the noiſe has paſſed. Commonly clear and calm weather follows this kind of northern lights. I have heard this account, not from one perſon only, but confirmed by the teſtimony of many who have ſpent part of ſeveral years in theſe very northern regions, and inhabited different countries from the Yeniſei to the Lena; ſo that no doubt of its truth can remain. This ſeems, indeed, to be the birthplace of the *aurora borealis* *."

This account of the noiſes attending the aurora borealis, allowing for ſome degree of exaggeration, has been corroborated by other teſtimonies.

522 Aurora australis. Similar appearances have likewiſe been obſerved towards the *ſouth* pole, and are therefore called *auroræ auſtrales*. The beſt account of theſe is given by Mr Forſter, who in his voyage round the world with Captain Cook, ſays that he obſerved them in high ſouthern latitudes, though attended with phenomena ſomewhat different from thoſe obſerved here. "On February 17. 1773, in ſouth lat. 58°, a beautiful phenomenon (he ſays), was obſerved during the preceding night, which appeared again this and ſeveral following nights. It conſiſted of long columns of a clear white light, ſhooting up from the horizon to the eaſtward, almoſt to the zenith, and gradually ſpreading on the whole ſouthern part of the ſky. Theſe columns were ſometimes bent ſideways at their upper extremities, and though in moſt reſpects ſimilar to the northern lights (aurora borealis) of our hemiſphere, yet differed from them in being always of a whitiſh colour, whereas ours aſſume various tints, eſpecially thoſe of a fiery and purple hue. The ſky was generally clear when they appeared, and the air ſharp and cold, the thermometer ſtanding at the freezing point."

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* *Phil. Tranſ.* vol. lxxiv. p. 228.

The periods of the appearances of the aurora borealis are very inconſtant. In ſome years they occur very frequently, and in others they are more rare; and it has been obſerved that they are more common about the time of the equinoxes than at other ſeaſons.

Dr Halley has given us a ſort of chronological hiſtory of the appearances which may be ranked under the *aurora borealis*; but for his account of the individual caſes we muſt refer to his paper in the Philoſophical Tranſactions Abridged, vol. iv.

The particular part of the atmoſphere in which theſe appearances take place, or the height above the earth to which they extend, is by no means certain; various philoſophers have attempted to aſcertain the height of various *auroræ boreales* by trigonometrical calculation; ſome have eſtimated them at a few hundreds, others at ſome thouſands of miles above the earth; but the reſults of their admeaſurements are ſo contradictory, that they cannot be relied on.

523 Aurora attributed by ſome to polar fires.

"Several of the moſt celebrated inquirers into nature have given their authority to ſome of the moſt extravagant theories, in attempting to aſſign its proper cauſe to the *aurora borealis*. Their imaginations have kindled bonfires in the poles of the earth, and they have repreſented the northern lights as the effects of flames, to which thoſe lights have ſcarcely any ſimilarity, and from which they are diſtinguiſhed by numberleſs diverſities.

"The ſalt-pits of the north were at one time regarded as emitting a luminous effluvium from their entrails, copious enough to pervade the whole of our northern atmoſphere. The diſcoveries of electricians have conſigned all theſe reveries to a ſhade, whence they would never return to excite the wonder of modern philoſophers, if the authors of them had not brought forth other productions, whoſe merits have made even their miſtakes immortal*."

524 Evidence for its electrical origin.

The evidence which we have for conſidering the *aurora borealis* as an effect of electricity, chiefly conſiſts of the following arguments.

1. If lightning be an effect of electricity, the ſame cauſe muſt, at a certain height in the atmoſphere, produce ſuch an appearance as is exhibited by the *aurora borealis*. The paſſage of the electric matter through air rarefied to a certain degree, is attended with all the undulating coruſcations of this meteor. Indeed there is ſcarcely a ſingle circumſtance attending the paſſage of a ſpark or a charge through an exhauſted tube, that does not bear a reſemblance to ſomething obſerved in the northern lights. The ſame peculiar motion, the ſame variety of colour, the ſame rapid alternations of flaſhes, occur both in the experiment, and in the natural phenomenon; the ſtreams of light in both are vivid and pointed; and if, in the experiment, the exhauſtion has been properly managed, ſome parts of the light will be marked with that reddiſh tinge, which in the *aurora borealis* has ſo often ſtruck the vulgar mind with terror and conſternation. The experiments to which we particularly allude are thoſe of the *conducting glaſs tube*, the *luminous conductor* and the *aurora borealis* deſcribed in N° 188—190.

2. The ſtriking diſtance of a charge of electric fluid paſſing through the air, increaſes according to the rarefaction of that medium. If, therefore, two clouds in oppoſite ſtates of electricity have no other circuit, it is probable that they will be diſcharged through the higher regions of the atmoſphere, more eſpecially if they are at ſuch an elevation, as renders their communication with the earth impracticable.

3. The ſame cauſes which tend to produce ſuch an accumulation of electricity in the atmoſphere as will bring on a thunder-ſtorm, have been found, in certain ſeaſons, and in the more northern climates, to be attended with an aurora borealis.

It muſt be confeſſed, however, that Mr Brook and Mr Bennet, in their obſervations on the electricity of the atmoſphere during an *aurora borealis*, could obſerve no particular ſigns of increaſed electricity, more than would have occurred in a ſerene ſky without any ſuch appearance.

4. A magnetic needle commonly appears a little diſturbed during a ſtrong *aurora borealis*.

We have already hinted at the connection between magnetiſm and electricity, and we ſhall fully illuſtrate this in the article MAGNETISM. Till this connection is fully explained, the force of this laſt argument can ſcarcely be ſeen.

525 Theory of theſe appearances.

A conſiderable difficulty attends even the moſt received theories of the *aurora borealis*, viz. the light appearing always to ſtrike from the poles towards the equator, rather than in the contrary direction. Perhaps this may be explained in the following manner. We ſhall aſſume the three following axioms.

1. *That all electrics when conſiderably heated, become conductors of electricity.*

2. *That, è converſo, non-electrics when ſubjected to violent degrees of cold, ought to become electrics.*

3. *That cold muſt alſo increaſe the electric powers of ſuch ſubſtances as are already electric.*

The air, all round the globe, at a certain height above its ſurface, is found to be exceedingly cold, and, as far as experiments have yet determined, exceedingly electrical. The inferior parts of the atmoſphere between the tropics, are violently heated during the daytime, by the reflection of the ſun's rays from the earth. Such air will, therefore, be a kind of conductor, and much more readily part with its electricity to the clouds and vapours floating in it, than the colder air towards the north and ſouth poles. Hence the prodigious appearances of electricity in theſe regions, ſhewing itſelf in thunder and other tempeſts of the moſt terrible kind. Immenſe quantities of the electric fluid are thus communicated to the earth; and the inferior warm atmoſphere having once exhauſted itſelf, muſt neceſſarily be recruited from the upper and colder region. This becomes very probable from what the French mathematicians obſerved when on the top of one of the Andes. They were often involved in clouds, which, ſinking down into the warmer air, appeared there to be highly electrified, and diſcharged themſelves in violent tempeſts of thunder and lightning; while in the mean time, on the top of the mountain, they enjoyed a calm and ſerene ſky. In the temperate and frigid zones, the inferior parts of the atmoſphere, never being ſo ſtrongly heated, do not part with their electricity ſo eaſily as in the torrid zone, and conſequently do not require ſuch recruits from the upper regions; but notwithſtanding the difference of heat obſerved in different parts of the earth near the ſurface, it is very probable that at conſiderable heights the degrees of cold are nearly equal all round the

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* Morgan's Lectures, vol. ii. p. 335.

the globe. Were there a like equality in the heat of the under part, there could never be any conſiderable loſs of equilibrium in the electricity of the atmoſphere; but as the hot air of the torrid zone is perpetually bringing down vaſt quantities of electric matter from the cold air that lies above it; and as the inferior parts of the atmoſphere lying towards the north and ſouth poles do not conduct in any great degree; it thence follows, that the upper parts of the atmoſphere lying over the torrid zone will continually require a ſupply from the northern and ſouthern regions. This eaſily ſhews the neceſſity of an electric current in the upper parts of the atmoſphere from each pole towards the equator; and thus we are alſo furniſhed with a reaſon why the *aurora borealis* appears more frequently in winter than in ſummer; namely, becauſe at that time the electric power of the inferior atmoſphere is greater on account of the cold than in ſummer; and conſequently the abundant electricity of the upper regions muſt go almoſt wholly off to the equatorial parts, it being impoſſible for it to get down to the earth; hence alſo the *aurora borealis* appears very frequent and bright in the frigid zones, the degree of cold in the upper and under regions of the atmoſphere being much more nearly equal in theſe parts than in any other. In ſome parts of Siberia particularly, this meteor appears conſtantly from October to Chriſtmas, and its coruſcations are ſaid to be very terrifying. Travellers agree that here the *aurora borealis* appears in its greateſt perfection; and it is to be remarked, that Siberia is one of the coldeſt countries in the world. In confirmation of this, it may alſo be obſerved, that from the experiments hitherto made with the kite, the air appears conſiderably more electrical in winter than in ſummer, though the clouds are known to be often moſt violently electrified in the ſummer time; a proof, that the electricity naturally belonging to the air, is in ſummer much more powerfully drawn off by the clouds than in winter, owing to the exceſs of heat.

A conſiderable difficulty, however, ſtill remains from the upright poſition which the ſtreams of the *aurora borealis* are generally ſuppoſed to have; whereas, according to our hypotheſis, they ought rather to run directly from north to ſouth. Dr Halley anſwered this difficulty by ſuppoſing his *magnetic effluvia*, (to which he attributed this phenomenon), to paſs from pole to pole in arches of great circles, ariſing to a great height above the earth, and conſequently darting from the places whence they aroſe like the radii of a circle; in which caſe, being ſet off in a direction nearly perpendicular to the ſurface of the earth, they muſt neceſſarily appear erect to thoſe who ſee them from any part of the ſurface, as is demonſtrated by mathematicans. It is alſo reaſonable to think that they will take this direction rather than any other, on account of their meeting with leſs reſiſtance in the very high regions of the air than in ſuch as are lower.

But the greateſt difficulty ſtill remains; for we have ſuppoſed the equilibrium of the atmoſphere to be broken in the daytime, and reſtored only at night; whereas, conſidering the immenſe velocity with which the electric fluid moves, the equilibrium ought to be reſtored in all parts almoſt inſtantaneouſly; yet the *aurora borealis* never appears except in the night, although its brightneſs is ſuch as muſt ſometimes make it viſible to us did it really exiſt in the day time.

In anſwer to this it muſt be obſerved, that though the paſſage of electricity through a good conductor is almoſt inſtantaneous, yet through a bad conductor it takes ſome time in paſſing. As our atmoſphere, therefore, unleſs very violently heated, is but a bad conductor of electricity; though the equilibrium in it is broken, it can by no means be inſtantaneouſly reſtored. Add to this, that as it is the action of the ſun which breaks the equilibrium, ſo the ſame action, extending over half the globe, prevents almoſt any attempt to reſtore it till night, when flaſhes ariſe from various parts of the atmoſphere, gradually extending themſelves with a variety of undulations towards the equator.

PART VI.

OF THE EFFECTS OF ELECTRICITY ON VEGETABLE LIFE.

526 Experiments on vegetation by

527 Mr Maimbray.

IT has been much diſputed whether electricity produces *any* effects on vegetables; and the experiments that have been made with the view of aſcertaining this point are moſt contradictory.

The firſt electrician who ſeems to have attended to this ſubject of inquiry was Mr Maimbray of Edinburgh, who, in the year 1746, electrified two myrtles during the whole month of October (i. e. we ſuppoſe, for ſome hours every day). The conſequence was, that in the following ſummer, theſe electrified myrtles put forth buds and bloſſoms ſooner than their neighbours who had been left to nature *.

527 Abbé Nollet.

Mr Maimbray was ſoon followed by the Abbé Nollet, who made ſome comparative experiments on the germination of ſeeds under ſimilar circumſtances, except that one pot was electrified three or four hours every day for fifteen days. The reſult of theſe experiments was ſimilar to that of Mr Maimbray's †.

528 M. Achard.

529 Dr Ingenhouſz.

Similar experiments were made by M. Achard of Berlin, and ſeveral other philoſophers, but ſtill with the ſame reſult; till Dr Ingenhouſz inſtituted a very complete ſet of experiments on the electrification of plants, which were communicated to the world through the medium of Rozier's Journal, at firſt by M. Swankhardt, and afterwards by Dr Ingenhouſz himſelf, in conſequence of ſome ſevere animadverſions which the communication of M. Swankhardt had called from M. Duvernier. By theſe experiments the faith of philoſophers with reſpect to the effect of electricity on vegetation was ſtaggered, as they were attended with reſults very oppoſite to thoſe of Maimbray, Nollet and Achard.

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* *Prieſtley's Hiſtory*, Part viii. ſect. 4.

† *Nollet Recherches.*

Effects of Electricity on Vegetation.

530 by Dr Carmay and l'abbe Ormoy.

Experiments have alſo been made by Dr Carmoy and the abbé D'Ormoy, rather more favourable to the firſt opinion; but the manner in which the electricity was applied appears very equivocal, as it is found that even ſhocks do not paſs through the body of the plant, but merely over its ſurface *.

531 By the abbe Bertholon.

But the moſt complete ſet of experiments on this ſubject has been made by the Abbé Bertholon, and theſe we ſhall give more in detail.

"In the firſt place (ſays the Abbé), there is continually and everywhere diffuſed in the atmoſphere (particularly in the upper regions) a conſiderable quantity of the electric fluid.

532 Electro-vegetometer deſcribed.

"This principle being granted: in order to remedy the deficiency of electric fluid which is ſuppoſed hurtful to vegetation, we muſt erect in the ſpot which we want to fecundate the following new apparatus, which has had all poſſible ſucceſs, and which I ſhall call by the name of the *electro-vegetometer*. This machine is as ſimple in its conſtruction as efficacious in its manner of acting; and I doubt not but it will be adopted by all thoſe who are ſufficiently inſtructed in the great principles of nature.

"This apparatus is compoſed of a maſt AB, fig. 131, or a long pole thruſt juſt ſo far into the earth as to ſtand firm and be able to reſiſt the winds. That part of the maſt which is to be in the earth muſt be well dried at the fire; and you muſt take care to lay on it a good coat of pitch and tar after taking it from the fire, that the reſinous particles may enter more deeply into the pores of the wood, which will then be dilated, at the ſame time that its humidity will be expelled by the heat. Care muſt likewiſe be taken to throw around that part fixed in the earth a certain quantity of coal duſt, or rather a thick layer of good cement, and to build beſides a baſe of maſon-work of a thickneſs and depth proportionable to the elevation of the inſtrument, ſo as to keep it durable and ſolid. As to the portion of it above the ground, it will be ſufficient to put upon it ſome coats of oil paint, except one chooſes rather to lay on a coat of bitumen the whole length of the piece.

"At the top of the maſt there is to be put an iron conſole or ſupport C; whoſe pointed extremity you are to fix in the upper end of the maſt, while the other extremity is to terminate in a ring, in order to receive the hollow glaſs tube which is ſeen at D, and in which there is to be glued an iron rod riſing with the point E. This rod, thus pointed at its upper extremity, is completely inſulated, by reaſon of its keeping a ſtrong hold of a thick glaſs tube, which is filled with a quantity of bituminous matter, mixed with charcoal, brick-duſt, and glaſs-powder; all together forming a ſufficiently good and ſtrong cement for the object in view.

To prevent rain wetting the glaſs tube, care muſt be taken to ſolder to the rod E a funnel of white-iron; which conſequently is entirely inſulated. From the lower extremity of the rod E hangs a chain G, which enters into a ſecond glaſs tube H, ſupported by the prop I. The lower end of the above-mentioned chain reſts upon a circular piece of iron wire, which forms a part of the horizontal conductor KLMN. In L is a breaker with a turning joint or hinge, in order to move to the right or left the iron rod LMN; there is likewiſe another in Q, to give ſtill greater effect to the circular movement. O and P are two ſupports terminating in a fork, where there is fixed a ſilken cord tightly ſtretched, in order to inſulate the horizontal conductor: in N are ſeveral very ſharp iron points.

533 Another form of this inſtrument.

"In fig. 132. you ſee an apparatus in the main like the former, but with ſome difference in the conſtruction. At the upper extremity of the maſt *a b* there is bored a hole into which enters a wooden cylinder *c*, which has been carefully dried before a great fire, in order to extract its humidity, dilate its pores, and ſaturate it with tar, pitch, or turpentine, applied at repeated intervals. The more heat the wood and bituminous matter receives, the more the ſubſtance penetrates, and the inſulation will be the more complete. It is moreover proper to beſmear the circumference of the little cylinder with a pretty thick coat of bitumen. This preparation being made, we next inſert the cylinder *c* into the hole *b* of the maſt; and it is eaſy to join together theſe two wooden pieces in the moſt perfect manner.

"At the upper extremity of the cylinder *c* we ſtrongly attach an iron rod *g f*; which, inſtead of one, is terminated by ſeveral ſharp points, all of gilded iron. In *e* you ſee a branch of iron reſembling the arm of an iron crow, from whence hangs an iron chain *h i*, at the end of which there is hooked a piece of iron reſembling a maſon's ſquare, and ending in a fork. The piece of iron *l* is a ring with a handle entering a little into the glaſs tube *m* filled with maſtich, in the ſame manner as does the iron rod *n*. The conductor *p o* is to be conſidered as an additional piece to act in that marked *p*. There are likewiſe put iron ſpikes in *q*: the ſupport *s* reſembles thoſe of O and P in the former figure. In this new machine you can lengthen or ſhorten the horizontal conductor as you pleaſe; and as the iron ring *l* turns freely in a circular gorge made in the maſt, the conductor is enabled to deſcribe the entire area of a circle.

534 Effects of theſe inſtruments.

"The conſtruction of this *electro-vegetometer* once well underſtood, it will be eaſy for us to conceive its effects. The electricity which prevails in the aerial regions will ſoon be drawn down by the elevated points of the upper extremity.

"The electric matter brought down by the point *E*, or by thoſe marked *f f f*, will be neceſſarily tranſmitted both by the rod and chain; becauſe the inſulation produced at the upper extremity of the maſt completely prevents its communication with the timber. The electric fluid paſſes from the chain to the horizontal conductor *KM* or *n o*: it then eſcapes by the points at *P* and *q*.

535 Method of uſing them.

"The manner of uſing this inſtrument is not more difficult than the knowledge either of its conſtruction or effects. Suppoſe, for example, we are to place it in the midſt of a kitchen garden. By making the horizontal conductor turn round ſucceſſively, you will be able to carry the electricity over the whole ſurface of the propoſed ground. The electric fluid thus drawn down, will extend itſelf over all the plants you want to cultivate; and this at a time when there is little or no electricity in the lower regions nigh the ſurface of the earth.

On the other hand, when it happens that the electric fluid ſhall be in too great abundance in the atmoſphere, in order to take off the effect of the apparatus in K, fig. 131. and in *n*, fig. 132. you have only to hang to it an iron chain reaching to the ground, or elſe

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* *Morgan's Lectures*, vol. ii.

elſe a perpendicular iron rod, which will have the ſame effect, *viz.* that of deſtroying the inſulation, and of inſenſibly tranſmitting the electric fluid in the ſame proportion as it is drawn by the points; ſo that there ſhall never be an overcharge of this fluid in the inſtrument, and its effect ſhall be either ſomething or nothing, according as you add or remove the ſecond chain or the additional rod.

“There will be nothing to fear from the ſpontaneous diſcharge of this apparatus, becauſe it is terminated below by proper points in P and *q* of both machines; However, it will be eaſy to furniſh one, by means of which we may approach the apparatus with perfect ſecurity; it is only neceſſary to hold the hand before it. This has the form of a great C, and is of a height equal to the diſtance that takes place betwixt the horizontal conductor and the ſurface of the earth. This diſcharger near the middle muſt be furniſhed with a glaſs handle; and at that extremity which is directed towards the conductor, there muſt hang an iron chain made to trail on the ground. This inſtrument is an excellent ſafeguard. See fig. 133.

536
Great advantages to be expected from theſe inſtruments.

“By means of the electro-vegetometer juſt now deſcribed, one may be able to accumulate at pleaſure this wonderful fluid, however diffuſed in the regions above, and conduct it to the ſurface of the earth, in thoſe ſeaſons when it is either ſcantily ſupplied, or its quantity is inſufficient for vegetation; or although it may be in ſome degree ſufficient, yet can never produce the effects of a multiplied and highly increaſed vegetation. So that by theſe means we ſhall have an excellent vegetable manure or nouriſhment brought down as it were from heaven, and that too at an eaſy expence; for after the conſtruction of this inſtrument, it will coſt nothing to maintain it: It will be moreover the moſt efficacious you can employ, no other ſubſtance being ſo active, penetrating, or conducive to the germination, growth, multiplication, or reproduction of vegetables. This heavenly manure is that which nature employs over the whole habitable earth; not excepting even thoſe regions which are eſteemed barren, but which, however, are often fecundated by thoſe agents which nature knows ſo well to employ to the moſt uſeful purpoſes. Perhaps there was nothing wanting to bring to a completion the uſeful diſcoveries that have been made in electricity, but to ſhow this ſo advantageous an art of employing electricity as a manure; conſequently, that all the effects which we have already mentioned depend upon electricity alone; and laſtly, that all theſe effects, viz. acceleration in the germination, the growth, and production of leaves, flowers, fruit, and their multiplication, &c. will be produced, even at a time when ſecondary cauſes are againſt it: and all this is brought about by the electric fluid, which we have the art of accumulating over certain portions of the earth, where we want to raiſe thoſe plants that are moſt calculated for our uſe. By multiplying theſe inſtruments, which are provided at little expence (ſince iron rods of the thickneſs of one's finger, and even leſs, are ſufficient for the purpoſe), we multiply their beneficial effects, and extend their uſe *ad infinitum*.

“This apparatus having been raiſed with care in the midſt of a garden, the happieſt effects were perceived, viz. different plants, herbs, and fruits, in greater forwardneſs than uſual, more multiplied, and of better quality. At the ſame time it was obſervable, that, during the night, the points P and *q*, as well as the upper extremities, were often garniſhed with beautiful luminous ſparks. Theſe facts are analogous to an obſervation which I have often made, viz. that plants grow beſt and are moſt vigorous near thunder-rods, where their ſituation favours their developement. They likewiſe ſerve to explain why vegetation is ſo vigorous in lofty foreſts, and where the trees raiſe their heads far from the ſurface of the earth, ſo that they ſeek, as it were, the electric fluid at a far greater height than plants leſs elevated; while the ſharp extremities of their leaves, boughs, and branches, ſerve as ſo many points granted them by the munificent hand of nature, to draw down from the atmoſphere that electric fluid, which is ſo powerful an agent in forwarding vegetation, and in promoting the different functions of plants.

537
Vegetation moſt vigorous near thunder rods.

538
How to augment the powers of vegetation by artificial electricity.

“It is not only by means of the electricity in the atmoſphere, collected by the above apparatus, that one can ſupply the electric fluid, which is ſo neceſſary to vegetation; but the electricity named *artificial* anſwers the ſame purpoſe. However aſtoniſhing the idea may be, or however impoſſible it may appear to realize it, yet nothing will be found more eaſy upon trial. Let us ſuppoſe that one wants to augment the vegetation of trees in a garden, orchard, &c. without having recourſe to the apparatus deſtined to pump down as it were the electricity from the atmoſphere, it is ſufficient to have a large inſulating ſtool. This may be made in two ways; either by pouring a ſufficient quantity of pitch and melted wax upon the above ſtool, whoſe borders being more raiſed than its middle, will form a kind of frame; or more ſimply, the ſtool (which is likewiſe called the *inſulator*) ſhall only be compoſed of a plate longer than broad, ſupported by four glaſs pillars, like thoſe uſed for electrical machines. One muſt take care to place above the inſulator a wooden tray full of water, and to cauſe mount upon the ſtool a man carrying a ſmall pump in the form of a ſyringe. If you eſtabliſh a communication between the man and an electrical machine put in motion (which is eaſily done by means of a chain that connects with the conductor of the machine), then the man thus inſulated (as well as every thing upon the ſtool) will be able, by puſhing forward the ſucker, to water the trees, by pouring upon them an electrical ſhower; and thus diffuſing over all the vegetables under its influence a principle of fecundity that exerts itſelf in an extraordinary manner upon the whole vegetable economy: and this method has moreover this advantage, that at all times and in all places it may be practiſed and applied to all plants whatever.

“Every one knows that the electricity is communicated to the water thus employed; and it would be eaſy to obtain the moſt ample conviction (if any one doubted it), by receiving upon his face or hand this electrical ſhower; he immediately feels ſmall punctures or ſtrokes, which are the effects of the ſparks that iſſue from each drop of water. This is perceived moſt ſenſibly if there is preſented a metal diſh to this electrical dew; for at the very inſtant of contact, brilliant flaſhes are produced.

“That the electricity received by the man from the chain

ELECTRICITY. Plate CLXXXVII.

Fig. 1.

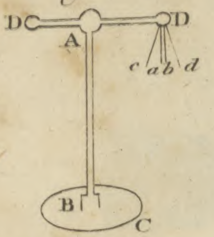


Fig. 2.

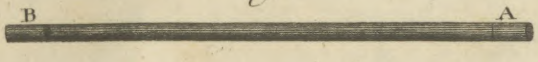


Fig. 4.

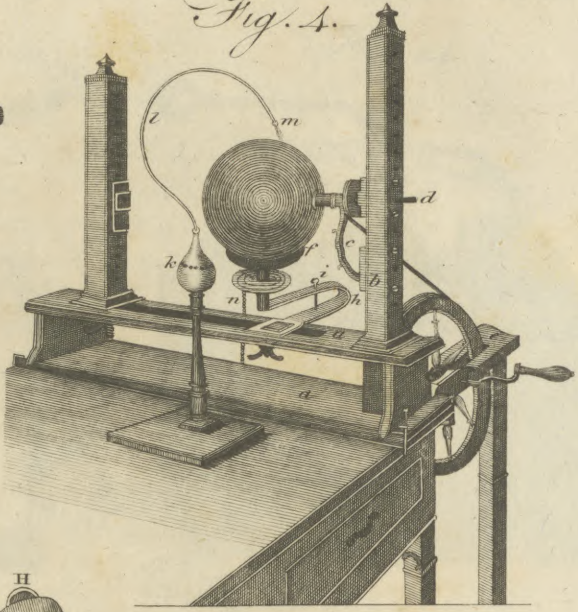


Fig. 5.

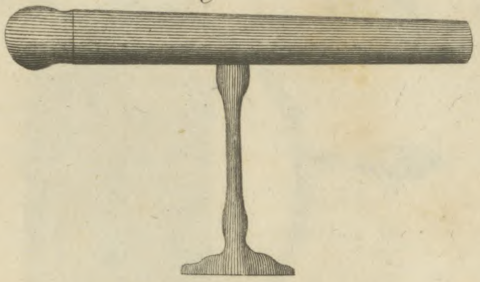


Fig. 3.

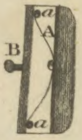


Fig. 6.

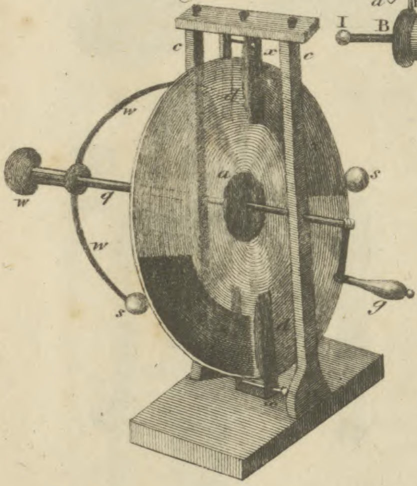


Fig. 7.

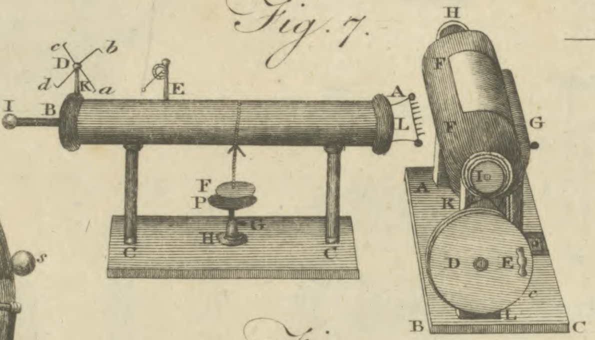
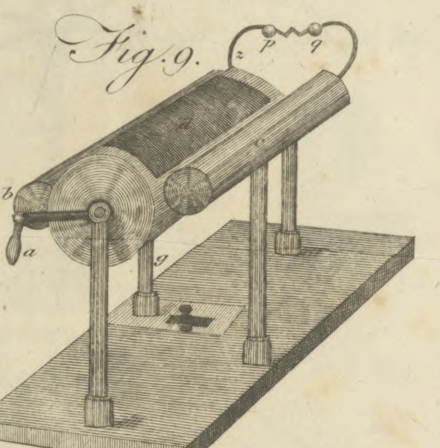


Fig. 9.



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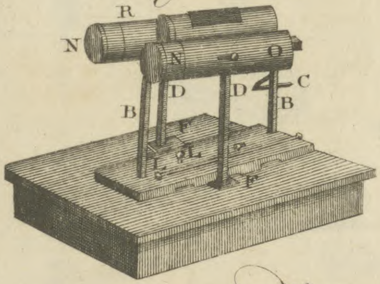

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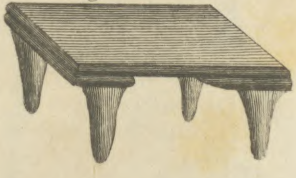

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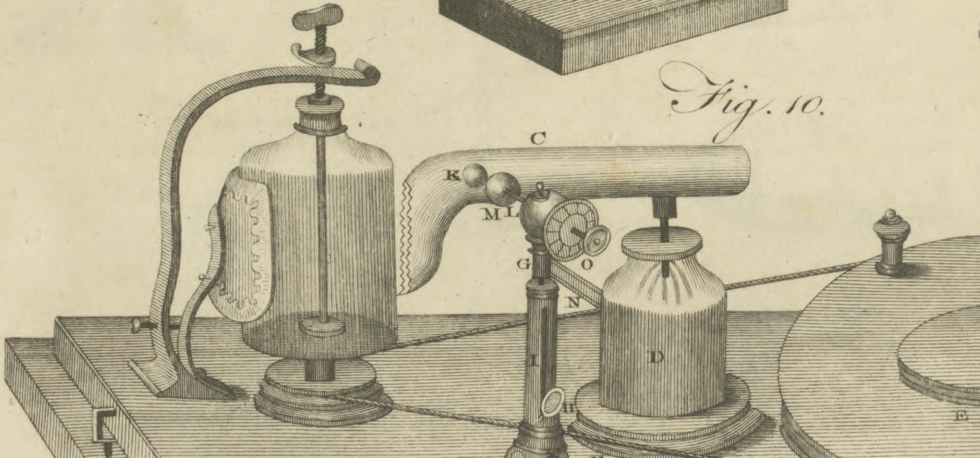
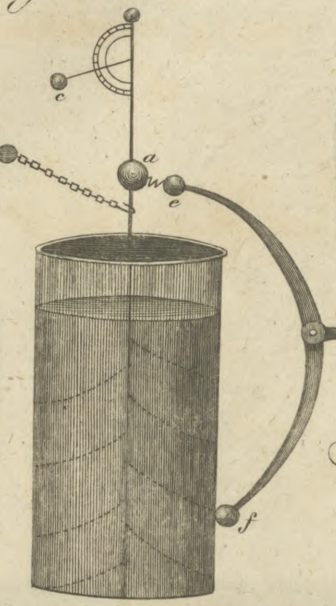


A. Bell Prin. Wal. Sculptor fecit.

ELECTRICITY.

Plate CLXXXVIII.

Fig. 12.



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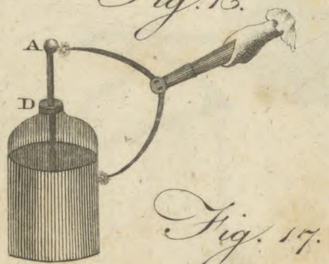

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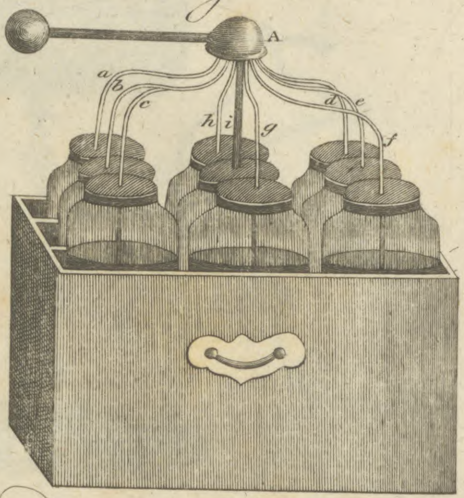

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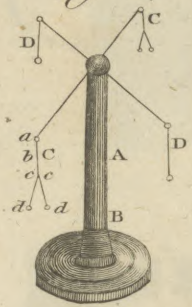

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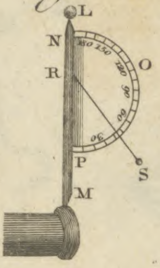

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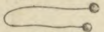

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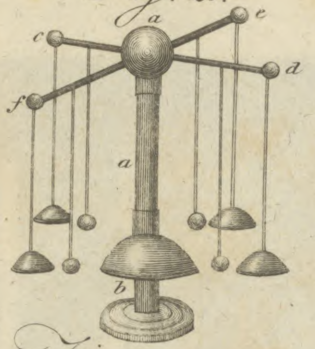
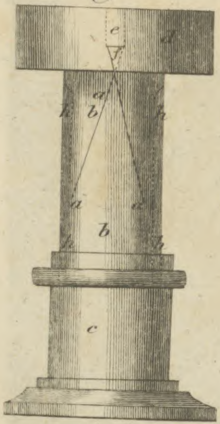


Fig. 20.

Fig. 22.

Fig. 18.



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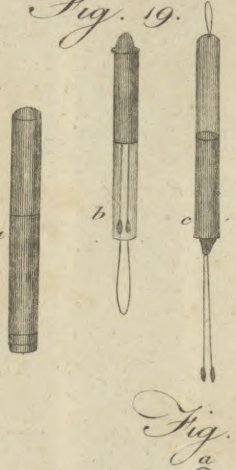

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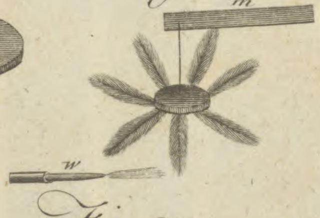
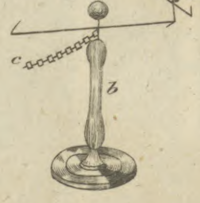


Fig. 24.

Fig. 26.



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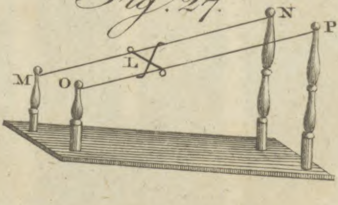

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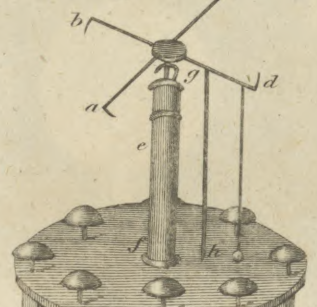
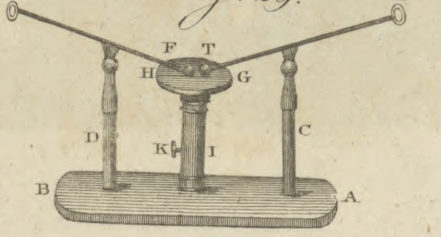


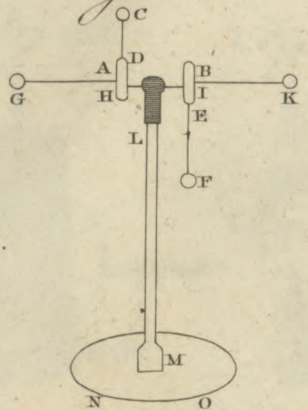
Fig. 28.

Fig. 29.



A. Bell Prin. Wal. Sculptor fecit.

Fig. 30.



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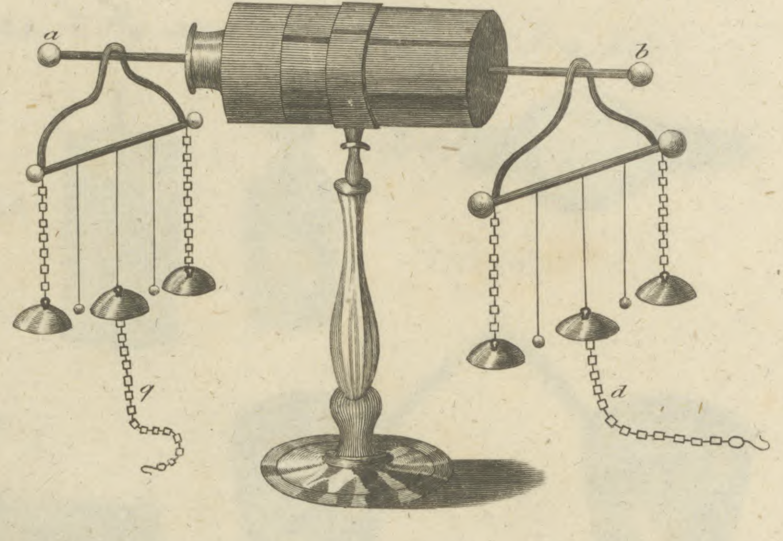

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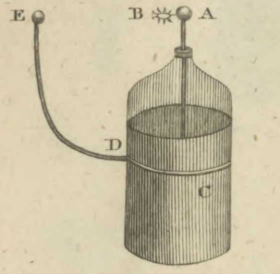

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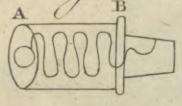


Fig. 32.

Fig. 41.

Fig. 40.

Fig. 39.

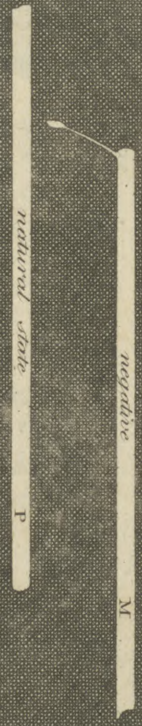


Fig. 38.

Fig. 37.

Fig. 35.

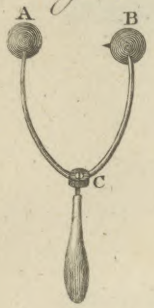
Fig. 36.

A. Bell Prin. Wal. Sculptor fecit.

ELECTRICITY.

Plate CXC.

Fig. 42.



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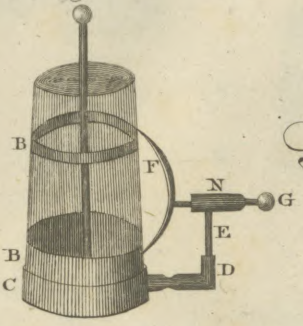


Fig. 44.

Fig. 45.

Fig. 46.

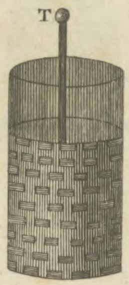
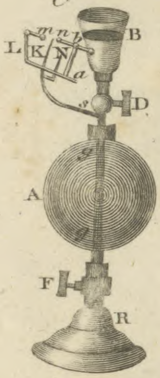


Fig. 47.

Fig. 48.

Fig. 49.



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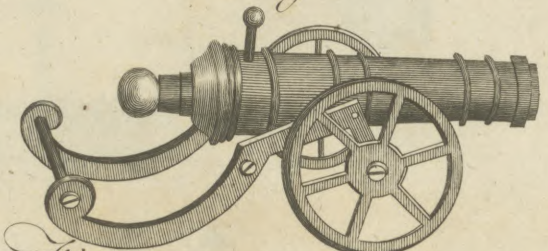

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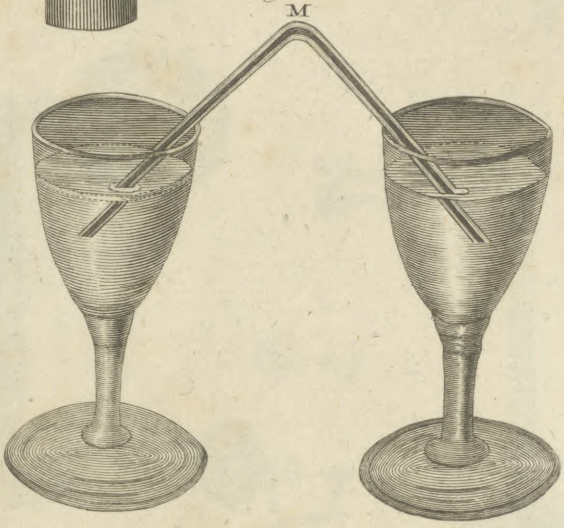
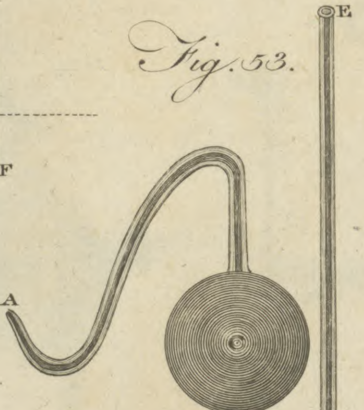


Fig. 52.

Fig. 53.



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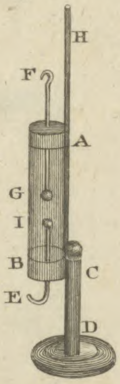

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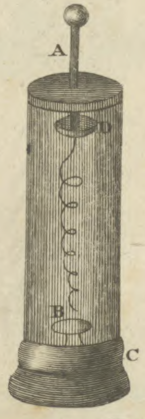

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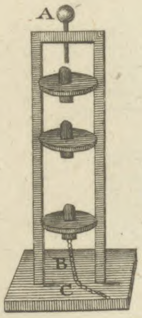

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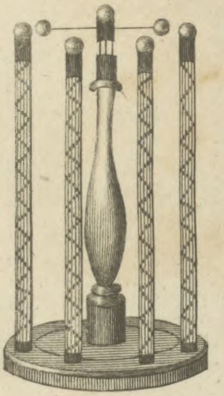

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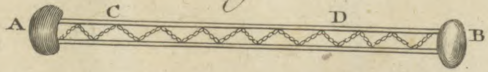

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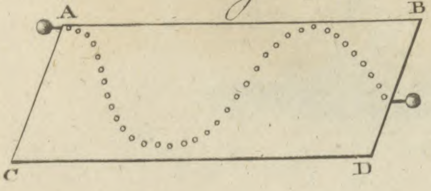

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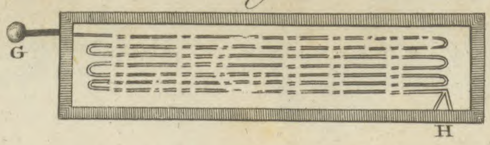

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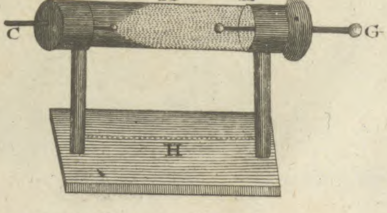
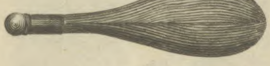


A. Bell Prin. Wal. Sculptor fecit.

Fig. 62.



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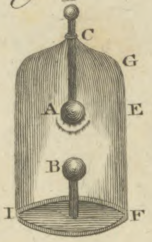
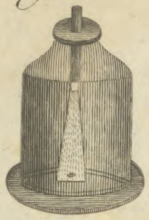


Fig. 64.

Fig. 65.



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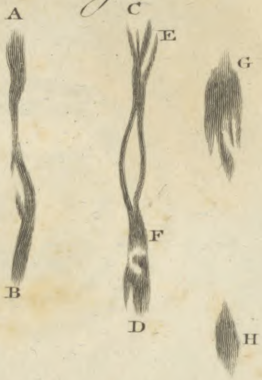

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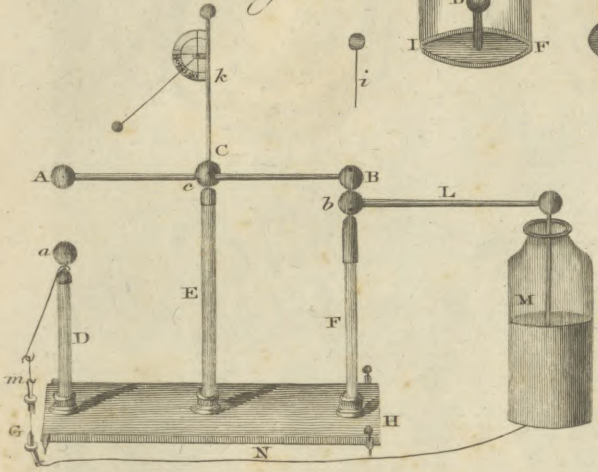

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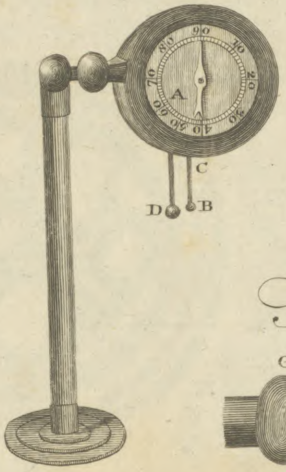

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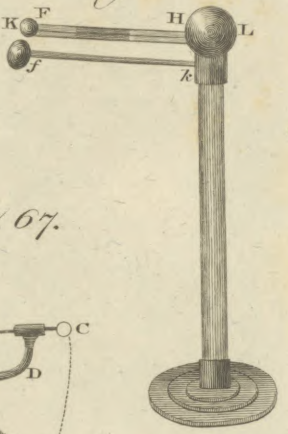

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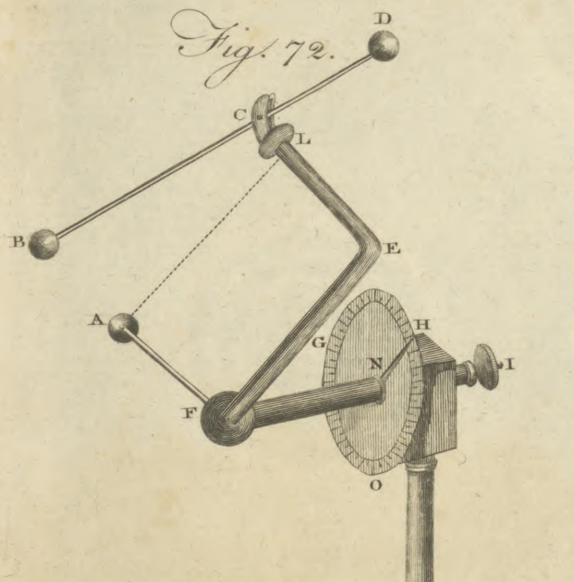

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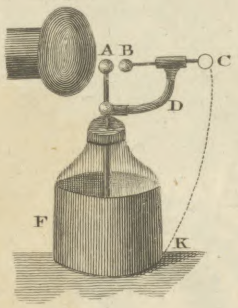

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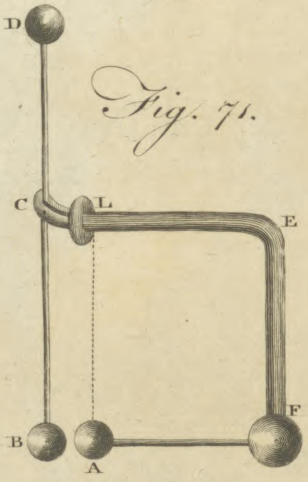

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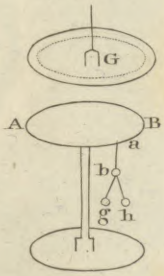

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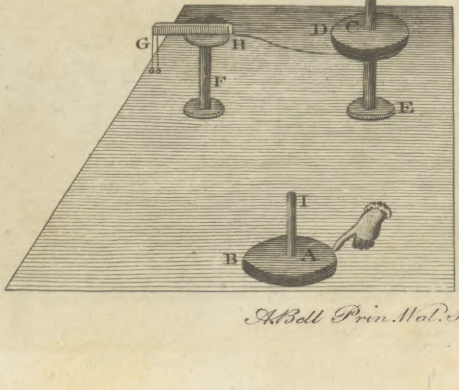
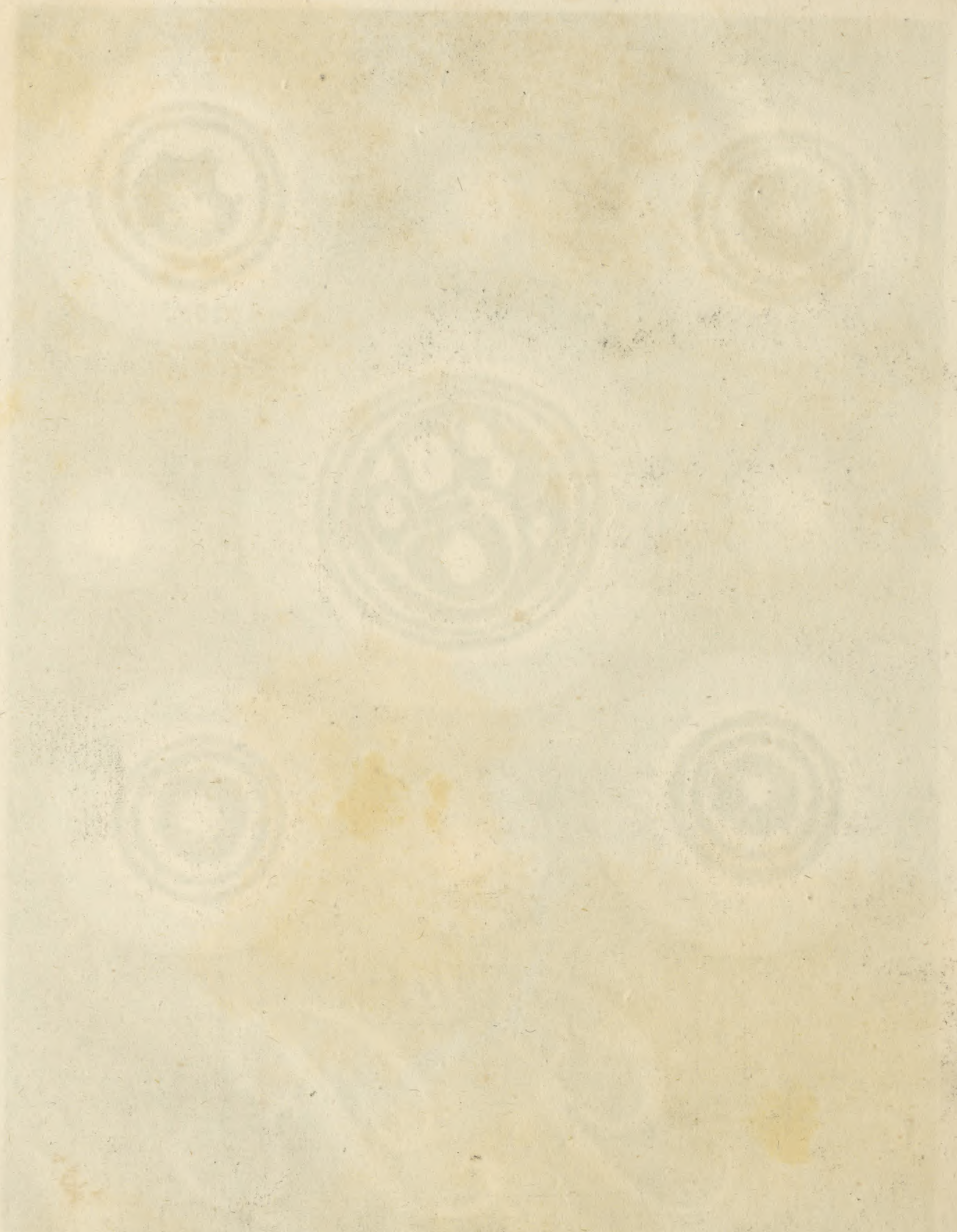


A. Bell Prin. Wal. Sculptor fecit.

A. Bell Prin. Wal. Sculptor fecit.



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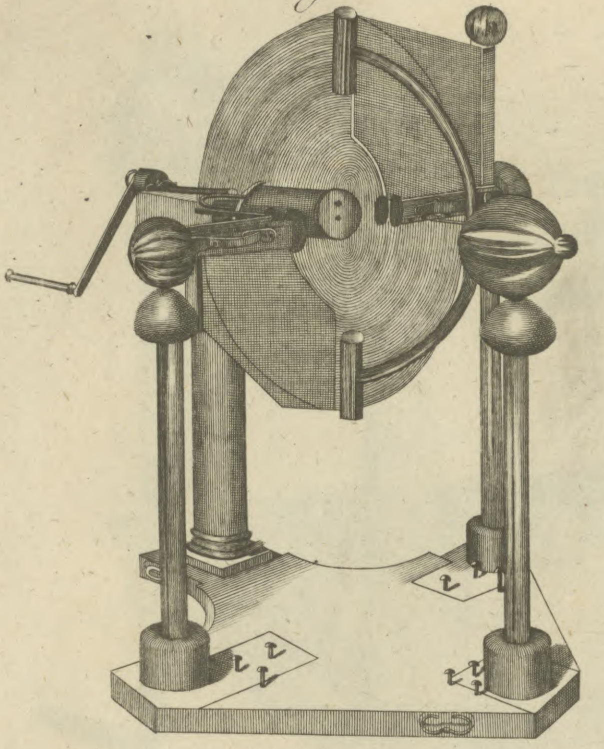

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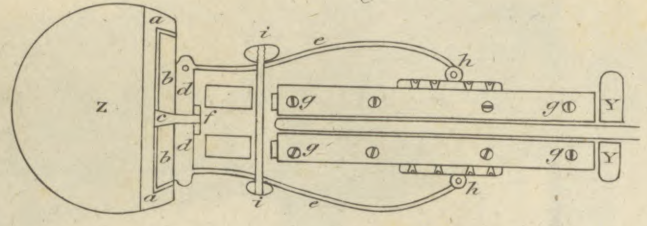

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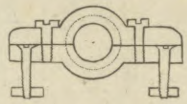

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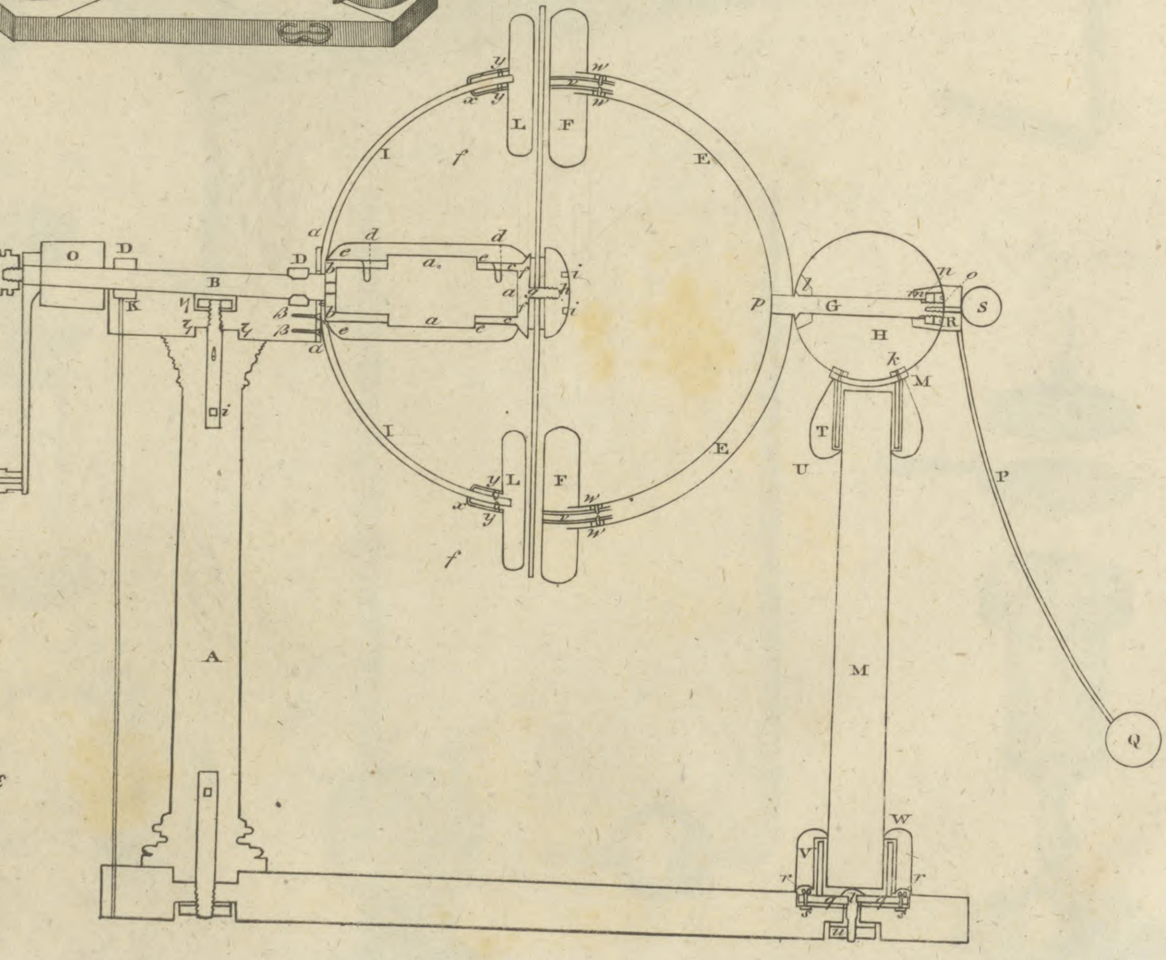

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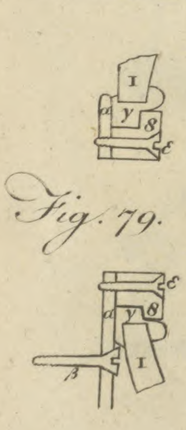


A. Bell Prin. Wal. Sculptor fecit.

Fig. 80.

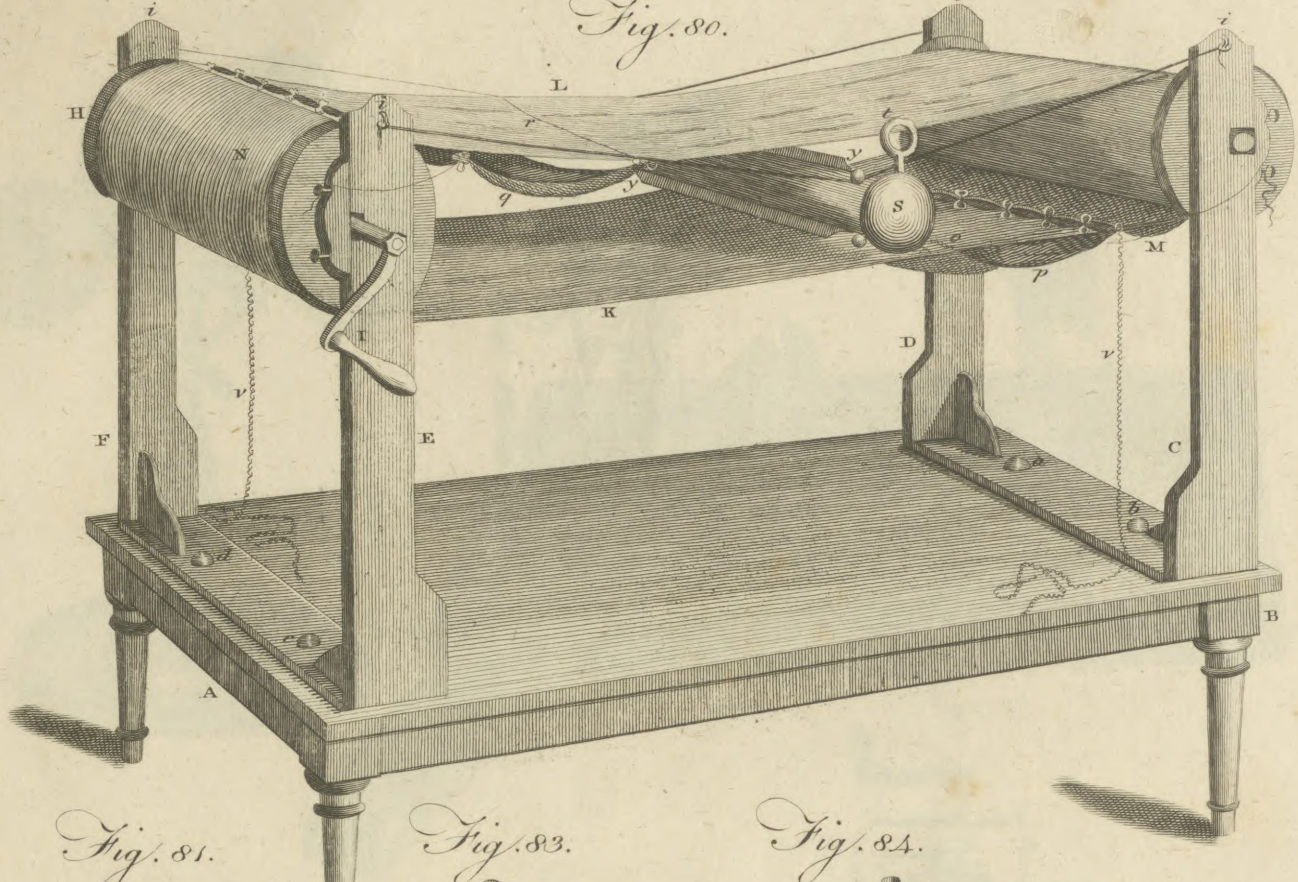
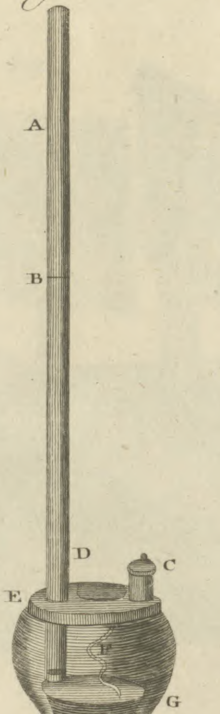


Fig. 81.

Fig. 82.

Fig. 83.



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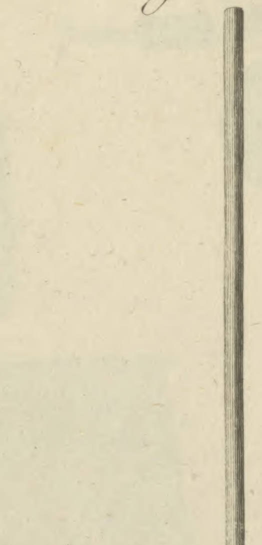

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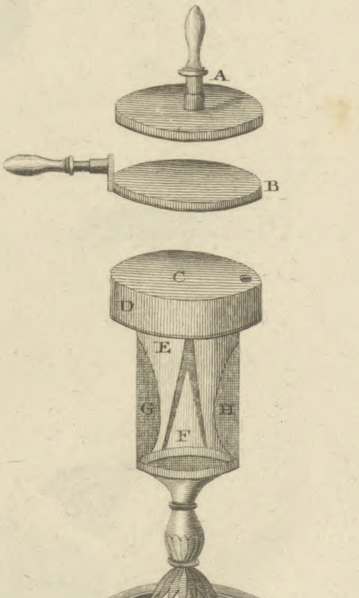

A. Bell Prin. Wal. Sculptor fecit.

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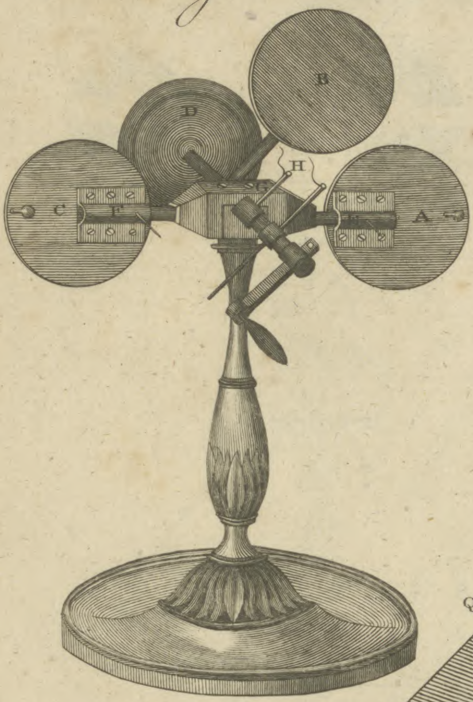

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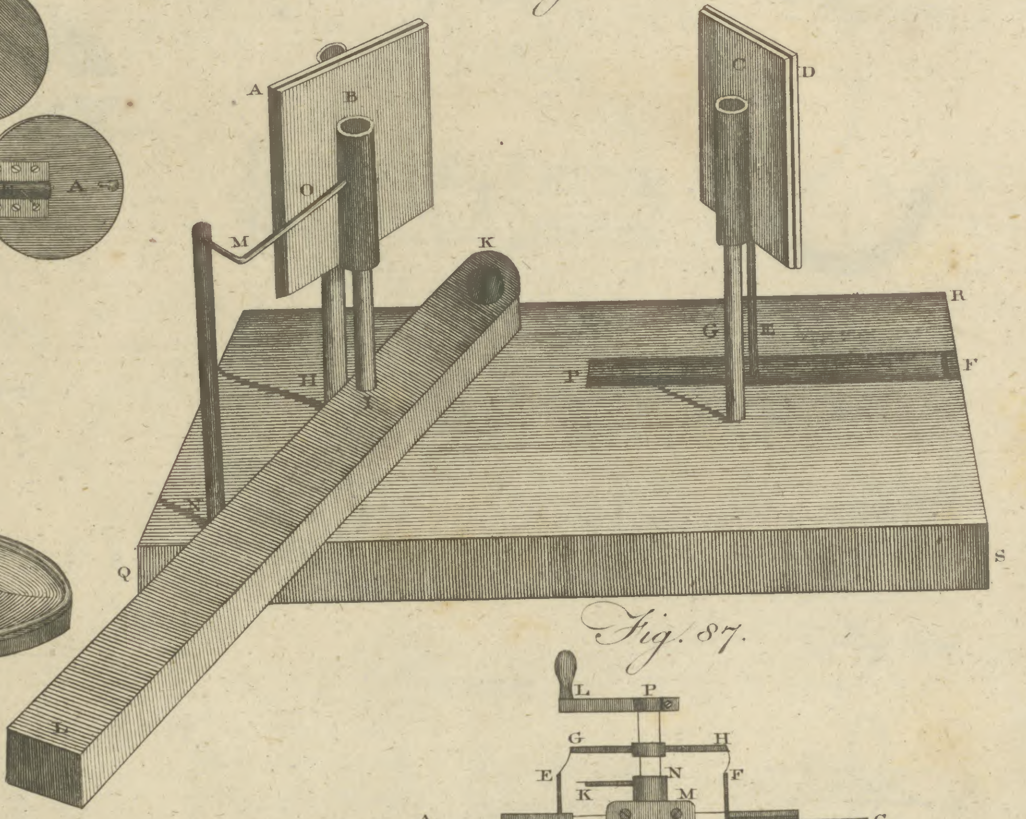

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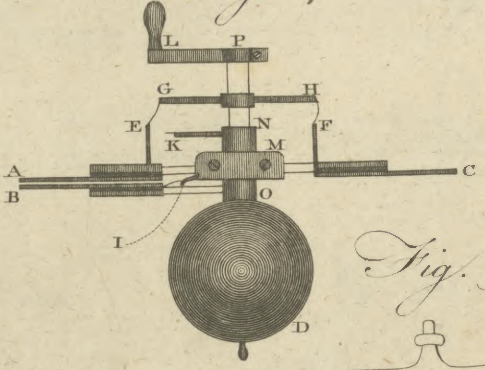

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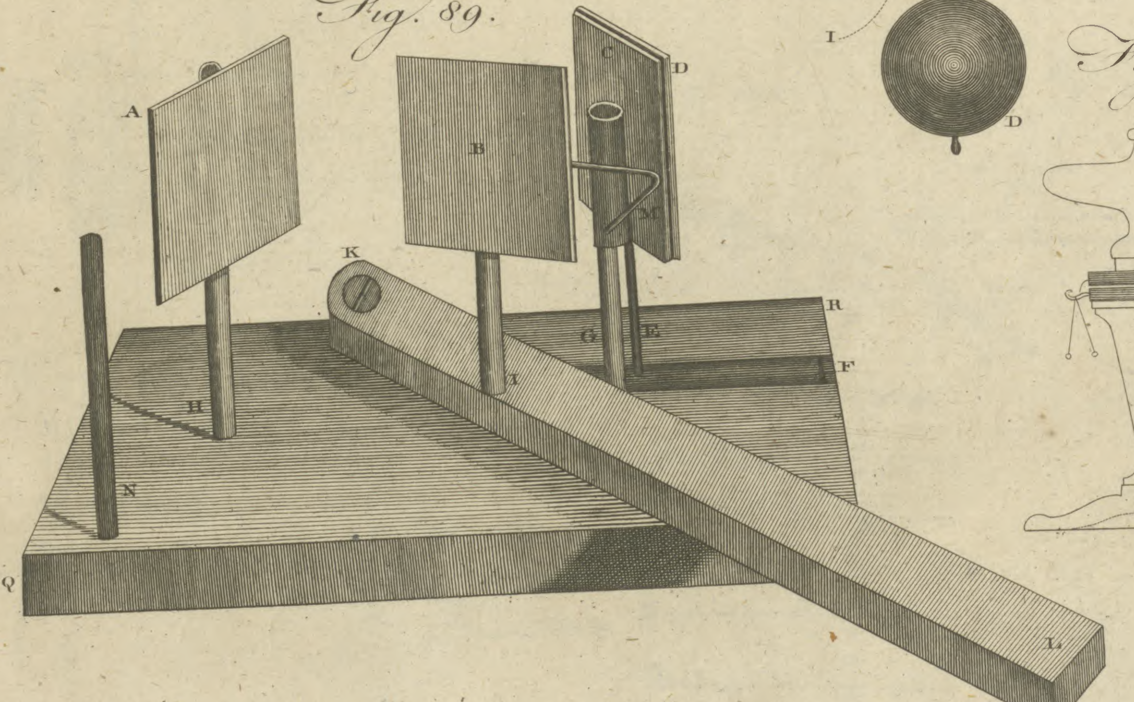

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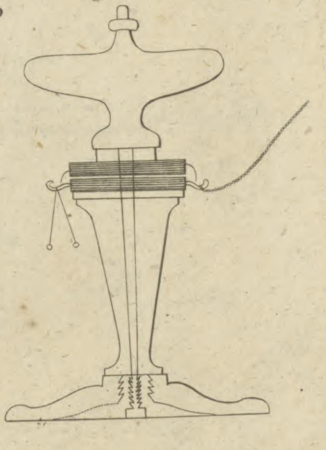
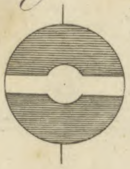


A. Bell Prin. Wal. Sculptor fecit.

Fig. 91.

Fig. 92.



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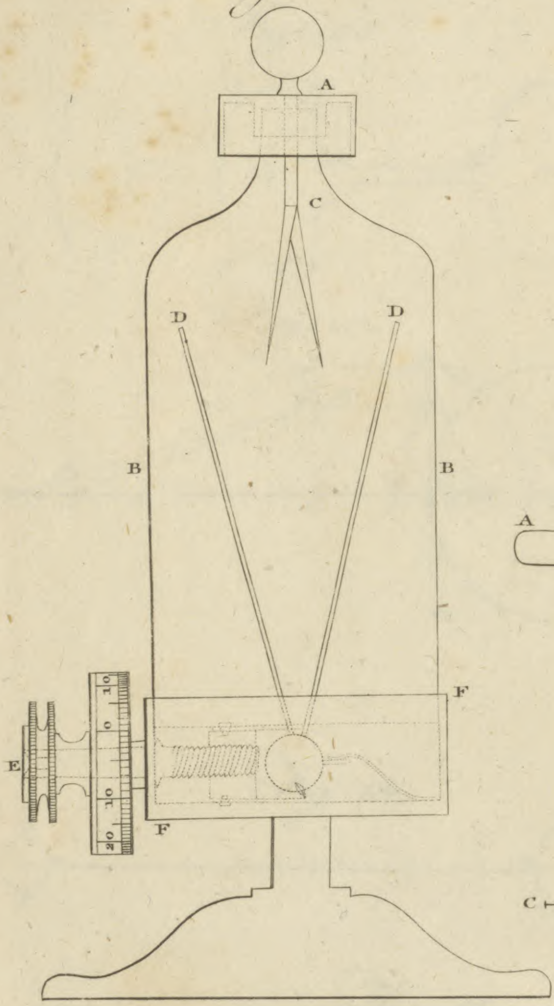

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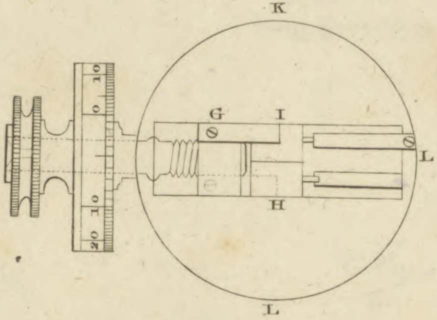

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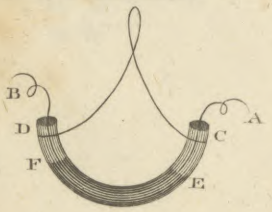
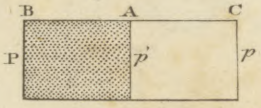


Fig. 96.



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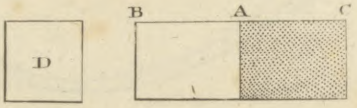

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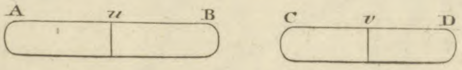

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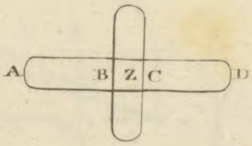

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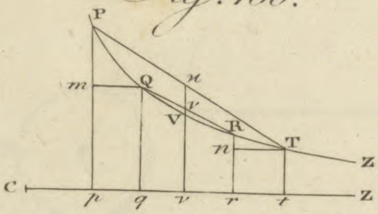

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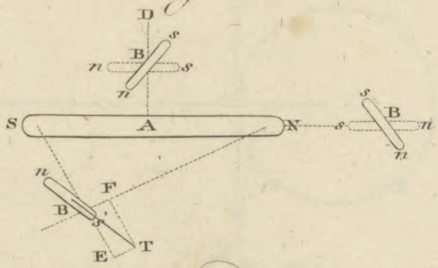

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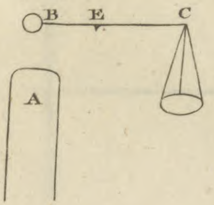

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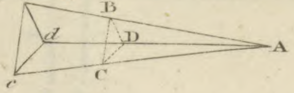

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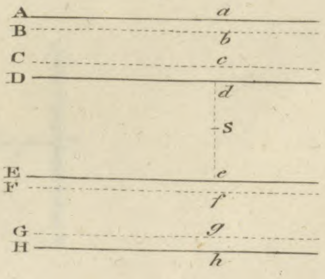

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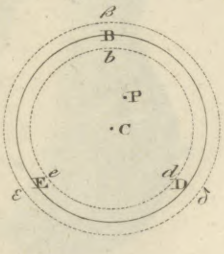

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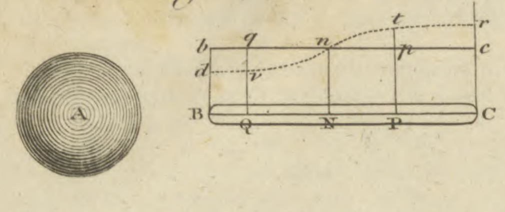

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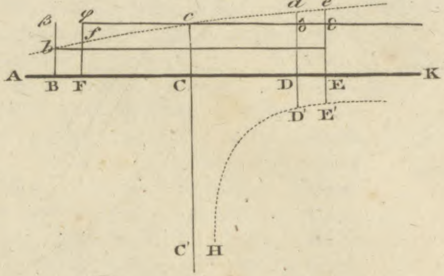

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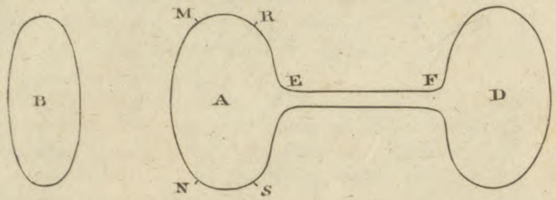

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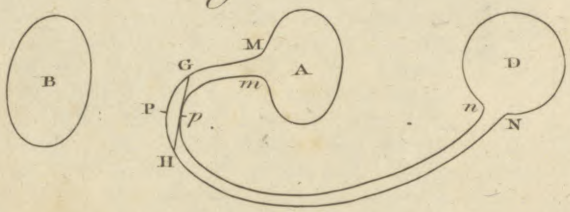

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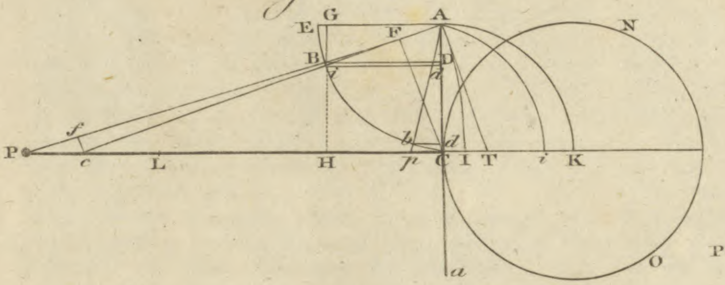

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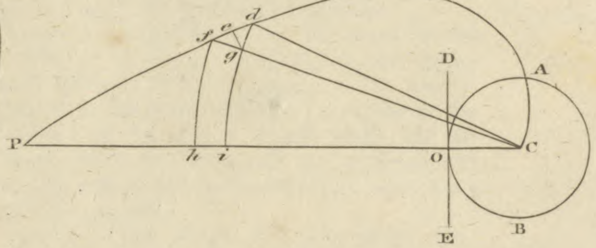

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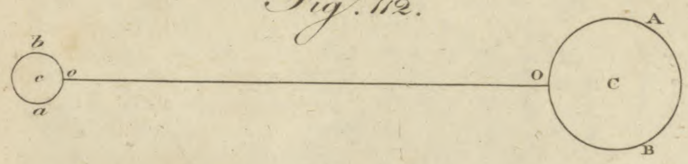

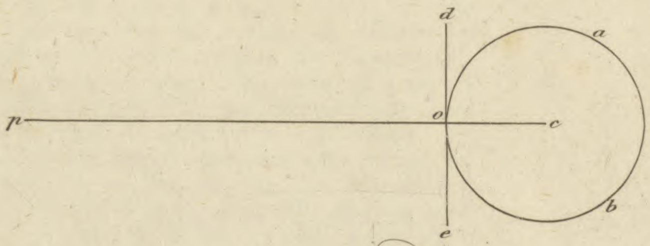

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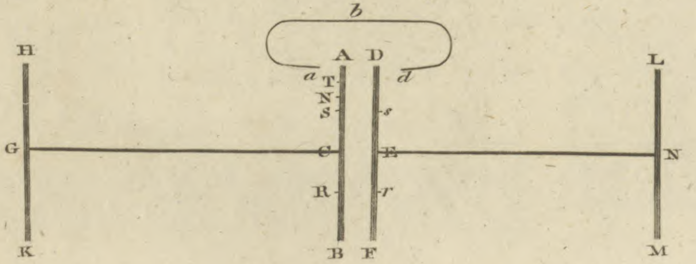

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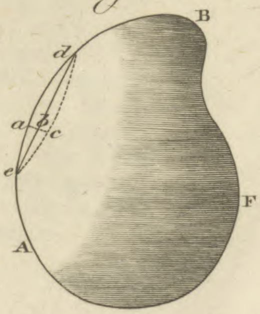

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Effects of Electricity on Vegetation.

chain may be communicated to the tray, we muſt put a ſmall cake of white iron, upon the end of which he may place his foot. The tray filled with water is a kind of magazine or reſervoir to ſerve as a continual ſupply to the pump. After watering one tree, you tranſport the ſtool to a ſecond, a third, and ſo on ſucceſſively; which is done in a ſhort time, and requires very little trouble.

"Inſtead of the chain, it is better to employ a cord or twiſt of pinchbeck or any other metal: by means of which there can be no loſs of the electric matter, as there is in the caſe of the chain by the ring points. Moreover, this metal cord or thread being capable of being untwiſted and lengthened, there will be no occaſion for tranſporting ſo often the electrical machine. It is almoſt needleſs to add, that this ſtring or metallic cord, which is always inſulated, may reſt upon the ſame kind of ſupports with thoſe which have been exhibited in OP and *s* of fig. 131. and 132. This method is ſimple, efficacious, and nowiſe expenſive, and cannot be too much employed.

539 Eaſy method of applying electricity in this manner.

"If one wants to water either a parterre or common garden, beds and platforms of flowers, or any other plots in which are ſown grain or plants of different ages and kinds, no method is more eaſy and expeditious than the following: Upon a ſmall carriage with two wheels there is placed a framed inſulator in form of a cake of pitch and roſin, as we have mentioned before in N° 538. The carriage is drawn the whole length of the garden by a man or horſe fixed to it. In proportion as you draw the carriage, the metallic cord winds itſelf upon a bobbin, which turns as uſual. This laſt is inſulated, either becauſe the little apparatus that ſuſtains the bobbin is planted in a maſs of roſin (when you chooſe the axle to be of iron), or elſe becauſe this moveable axis is a tube of ſolid glaſs. There muſt alſo be a ſupport, which ſerves to prevent the gold thread or the metallic cord from trailing on the ground, and thus diſſipating the electricity; and, moreover, it ſerves as an inſulator. To accompliſh this laſt purpoſe, it is neceſſary that the ring into which it paſſes be of glaſs. One may likewiſe employ the inſulators and ſupports marked OP and *s*, in fig. 131. and 132. If a gardener, mounted upon an inſulator, holds in one hand a pump full of water, and with the other takes hold of a metallic cord, in order to tranſmit the electricity which comes from the conductor; in this caſe, the water being electrified, you will have an electrical ſhower; which falling on the whole ſurface of the plants which you want to electrify, will render the vegetation more vigorous and more abundant. A ſecond gardener is to give additional pumps full of water to him who is upon the inſulator, when he ſhall have emptied thoſe he holds; and thus in a little time you will be able to electrify the whole garden. This method takes hardly longer time than the ordinary one; and although it ſhould be a little longer, the great advantages reſulting from it will abundantly recompenſe the ſmall additional trouble.

"By repeating this operation ſeveral days ſucceſſively, either upon ſeed ſown or plants in a ſtate of growth, you will very ſoon reap the greateſt advantages from it. This operation, equally eaſy with the preceding deſcribed upon the ſubject of watering trees, has been put in practice with the greateſt ſucceſs. Several other methods, anſwering the ſame purpoſe, might be deviſed; but they are all of them pretty ſimilar to that juſt deſcribed.

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540 To electrify water kept in reſervoirs, &c.

"I cannot finiſh this article without mentioning another method relative to the preſent object, although it be much leſs efficacious than the preceding ones. It conſiſts in communicating to water kept in baſons, reſervoirs, &c. (for the purpoſe of watering), the electric fluid, by means of a good electrical machine. To this end, one muſt plaſter over with a bituminous cement all the interior ſurface of the baſon deſtined to receive the water that ſerves for irrigation; the nature of this cement anſwering the purpoſe of inſulation, will prevent the electric fluid that communicates with the water from being diſſipated; and the water thus charged with electricity will be the more fitted for vegetation.

541 Vegetables injured by the electric ſhock.

"If the deficiency of the electric fluid, or rather a ſmall quantity of it, is apt to be hurtful to vegetables, a too great abundance of this matter will likewiſe ſometimes produce pernicious effects. The experiments made by Meſſrs Nairne, Banks, and other learned men of the Royal Society of London, prove ſufficiently this truth. An electric battery, very ſtrong, was diſcharged upon a branch of balſam ſtill holding by its trunk. Some minutes after, there was obſerved a remarkable alteration in the branch, of which the leſs woody parts immediately withered, dropped towards the ground, died next day, and in a ſhort time entirely dried up; at the ſame time that another branch of the ſame plant that had not been put under the electric chain, was not in the ſmalleſt degree affected.

"This experiment repeated upon other plants ſhowed the ſame effects; and it was remarked that the attraction, occaſioned by a ſtrong diſcharge of the electricity, produced an alteration different according to the different nature of the plants. Thoſe which are leſs woody, more herbaceous, more aqueous, experience in proportion, impreſſions that are ſtronger and much more ſpeedy in their operation.

"A branch of each of the following plants, compoſing an electrical chain, it was obſerved by theſe able philoſophers, that the balſam was affected by the diſcharge of the battery in a few moments after, and periſhed next day. The leaves of a marvel of Peru did not drop till the day following that; and the ſame phenomenon happened to a geranium. Several days elapſed before there was obſerved any fatal effect on the cardinal flower. The branch of a laurel did not ſhow any ſymptoms till after the lapſe of about 15 days, after which it died; but it was a full month before they perceived any ſenſible change on the myrtle; at the ſame time they conſtantly obſerved that the bodies of thoſe plants and branches which had formed no part of the chain, continued to be freſh, vigorous, and covered with leaves in good condition *.

"It hardly ever happens that the ſuperabundance of the electric fluid exiſting in a ſmall portion of the atmoſphere where a plant is ſituated, can be ſo great as that which took place by the exploſion of the ſtrong battery of Mr Nairne, directed particularly upon one branch; or if this ſhould happen, it can only be upon a few individual plants in a very ſmall number.

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* *Phil. Tranſ.* vol. lxiv.

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Leyden

S

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